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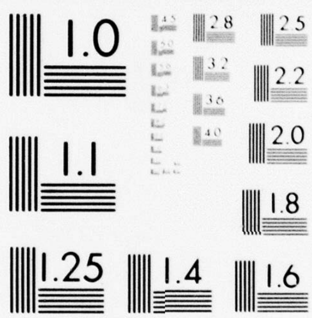

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DESIGN FABRICATE AND TEST INSTRUMENTATION FOR ROCKETBORNE MEASUREMENTS OF VEHICLE CHARGING.

15 F19628-76-C-0230

10 William B./Huber

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Rocketborne Vehicle Charging

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Instrumentation for the measurement of vehicle charging was designed, fabricated, tested and integrated into an Astrobee F Rocket Payload.

The vehicle was stimulated with an electron beam ejection system and a positive ion beam system, automatically programmed for sequential beam ejection in twelve modes of operation lasting

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one-half second each.

The vehicle potential measurements were made with a dual retarding potential analyzer system, four thermal emissive passive probes mounted on booms and an inter-segment bipolar voltmeter with peak detectors and sample-and-hold amplifiers looking for large transients at the mode changes.

A camera was employed to view corona discharges along the exterior surface of the payload as well as view any discharges between isolated sections of the payload.

All instruments and camera were programmed along with the particle guns for optimum parameters during each part of the program cycle.

A PCM telemetry format was used to accommodate 90 channels of instrument data.

LEVEL II

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1. INTRODUCTION

The objective of this contract was the design, fabrication, testing and integration of rocket borne instrumentation for the measurement of vehicle charging, including auxiliary electronics instrumentation and ground support equipment with the provision of field services for prelaunch testing of the integrated rocket payload at White Sands Missile Range, New Mexico.

2. SYSTEM DESIGN

The payload was designed for an Astrobe F vehicle with a maximum altitude of 250 kilometers. The payload was divided into three sections below the ejectable nose cone: The pressurized particle beam system, the electronics section, and an insulated cylindrical section for the bipolar voltmeter sensoring surface which contained the recovery parachute.

The pressurized section was built such that when the nose cone was ejected and the electron and ion beam system caps were opened, all with timed electro-explosive devices, the particle beams were ejected in a line parallel to the vehicle spin axis.

The electronics section was unpressurized. It contained the telemetry and beacon electronics, the retarding potential analyzer sensors and

electronics, the boom-mounted thermal emissive probes, surface potential monitor designed and built by Aerospace Corporation, transient pulse monitor designed and built by Stanford Research Institute, electronic instrument programmer, sensor postamplifiers, power supplies, batteries, payload timers, power relays, and camera. This section provided all the ejectable doors for booms, retarding potential analyzers and camera.

2.1 Particle Beam Systems

The electron beam system was designed around the Machlett Model EE65-2 electron gun. The system was similar to an electron beam system developed under Contract F19628-75-C-0124, but modified to produce 100 watts of beam power (35 milliamperes at 3.0 kilovolts.)

The ion beam system was developed by Hughes Research Laboratories of Malibu, California, under Contract F19628-76-C-0272.

2.1.1 Electron Beam System Details

The EE65 electron gun was designed by Machlett Laboratories for space flight applications. The heater and control grid assembly is the same as that of a power triode. In addition, there is a focusing anode ring and accelerating anode ring forming the electron beam

optics, and a hermetically sealed end cap used for evacuation at fabrication and as a collector for the beam during closed tube operation.

The original design made use of a electrically induced heat stress on a ceramic cylinder between the end cap and the anode ring, causing the cylinder to crack evenly around the tube. A spring loaded arm attached to the end cap then carried the cap to the side of the tube assembly, exposing the electron beam to the outside environment.

The EE65-2 design modification eliminated the moly-manganese heater band fired on the ceramic cylinder and called for a beveled end of the ceramic tube where the end cap is brazed to the ceramic tube. This resulted in a weaker joint, allowing the use of redundant wedge mechanisms activated by electro-explosive devices to separate the end cap from the ceramic tube. The same spring loaded arm device was used to carry the end cap to the side of the tube assembly. The cap removal mechanism was designed by William Lynch of AFGL.

A pressure seal at the electron gun penetration used a 3/8 inch thick silicon rubber washer between the anode ring and the machined surface of the front wall of the pressurized section.

The schematic for the electron gun power and control circuits is shown on Drawing D-938. U_1 is a 24 volt regulator supplying power to the 5 KH_z, saturating inverter composed of Q_1, Q_2 and T_1. The secondaries of T_1 supply: AC heater power for the electron gun, a floating 50 volt supply for the amplifier for the electron gun control grid, and base drive power for the two high voltage power inverters using T_2 and T_3. The heater winding and the floating 50 volt supply winding are operated at as much as 3000 volts negative with respect to ground or vehicle frame. The T_1 inverter is designed to operate from before vehicle lift-off.

The T_2 and T_3 inverters each supply 1.5 KV at 35 milliamperes. They are non-saturating, slaved to the T_1 inverter described above. The secondary high voltage rectifier outputs are wired in series such that the net high voltage may be either 1.5 KV with only inverter T_3 on, or 3.0 KV with both T_2 and T_3 inverters on. The unregulated 28 volt

power for both of these inverters is switched on at proper vehicle altitude through a power relay on the power control deck in the electronics section.

This relay is actuated by a timer. K_1 is used to switch power to the T_2 inverter as a function of experiment mode determined by the electronic programmer located in the electronics section.

Beam current control is achieved by the closed loop of the active elements U_8, Q_{12}, Q_{11}, U_{10}, Q_{10}, U_5, and the electron gun.

U_8 is an electrometer with gain switched by relays K_2 and K_3. R_{31}, 6.34 K, is across the amplifier at all times. In the one milliampere mode of operation (M_9), K_2 and K_3 are open. All of the electron beam current, whether through the cap and amplifier U_4, or through the open gun and the environment to the vehicle frame, must pass through the feedback resistors of U_8. The amplifier maintains its input at the reference voltage of pin 3, or zero volts. A beam current of one milliampere through R_{31}, 6.34 K, causes the output on the

emitter of Q_{12} to go towards -6.4 volts; which is the value of reference diode CR_{20}. At this point Q_{11} starts to turn off, reducing the current to the photo-diode of opto-isolator U_{10}. This in turn reduces the current through the grounded base amplifier, Q_{10}, and causes the output of operational amplifier U_5 to go negative, shutting down the electron beam in the gun.

The control loop then is such that the output of the trans-resistance amplifier, U_8, goes to -6.4 volts by adjusting the beam current of the EE65-2 electron gun. The electron gun current is therefore 6.4 volts divided by the resistance placed across U_8.

When only K_2 is closed (during M_{10}), R_{38} is placed in parallel with R_{31} producing a parallel resistance of 495 ohms and a beam current of 13 milliamperes. When K_2 and K_3 are closed (during M_{11})R_{38},R_{39},R_{59} and R_{60} are all in parallel with R_{31} producing a resistance of 182 ohms and a beam current of 35 milliamperes.

U_4 is a cap current monitor amplifier with a linear gain of R_{54} or 130 volts per ampere or 4.55 volts per 35 milli-ampere.

U_9 is a frame current amplifier with a gain of -.619 volts per volt or +4 volts out for -6.4 volts in. This is a telemetry monitor of the -6.4 volt output of the trans-resistance amplifier, U_8 and knowing the gain of amplifier U_8 as a function of mode, is a monitor of the amplitude of the frame current due to the electron beam.

In mode 9, +4 volts output is equivalent to one milliampere input; in mode 10, +4 volts out is equivalent to 13 milliamperes in. In mode 11, +4 volts out is equivalent to 35 milliamperes in.

Resistor divider string R_{15} through R_{30} provide a focus anode voltage and a high voltage monitor for telemetry. About 3.2 percent of the high voltage is dropped across R_{15} making the focus anode about 90 volts more positive than the electron gun cathode when the beam voltage is at 3 KV, and about 45 volts more positive when at 1.5 KV.

The voltage across R_{30} (7.5 K) is .133 percent of the high voltage. The bottom of R_3 is held at ground potential by operational amplifier U_8. Voltage follower, U_6, samples this voltage without loading the divider (the input impedance is in the order of 10^{10} ohms).

U_7 is a buffer amplifier with a gain of -1. The high voltage monitor gain from the negative high voltage is +4 volts per -3000 volts.

The anode ring of the electron gun is returned to input side of R_{31}. This maintains the ring at ground potential but returns any anode ring current from the internal electron beam to the high voltage positive return without being measured and controlled by the frame current monitor circuits.

Mode signals M_9, M_{10} and M_{11} are successive positive five volt signals, about one-half second long, developed in the instrument programmer located in the electronics section.

R_{66}, R_{67} and a pressure switch monitor the pressure of the pressurized section. The switch remains open at atmospheric pressure, providing a monitor voltage of +4 volts to telemetry. Should the pressure vent during vehicle ascent, the switch closes at a pressure equivalent to 50,000 feet, reducing the monitor voltage to zero.

R_{65} and a thermistor mounted on the main wall of the pressurized section monitor the temperature. The transfer characteristic of this circuit is:

$$T(^{\circ}C) = \frac{1}{A+B \ln R_T + C(\ln R_T)^3} - 273$$

where $$R_T = \frac{15.8\ Eo}{15 - Eo} \times 10^3 \text{ ohms}$$

and $A = 1.276 \times 10^{-3}$

$B = 2.380 \times 10^{-4}$

and $C = 8.575 \times 10^{-8}$

At 5.0 volts out, the temperature is $+15^{\circ}C$. At 0.5 volts out the temperature is $+85^{\circ}C$.

2.1.2 Positive Ion Beam System

The Hughes Research Laboratories Positive Ion Beam System design consists of three sub-assemblies: ion source, expellant assembly, and power processor assembly.

A light magnesium structure package holds the three sub-assemblies into one package such the electronics and the expellant assembly can be maintained at atmospheric pressure in the pressurized section of a rocket. The ion source is packaged in a vacuum tight enclosure with a cover which can be released with an electro-explosive device. The cover and release mechanism was designed by W. Lynch of AFGL.

The expellant gas is xenon. The gas reservoir is connected to the ion source cathode using an electrically operated latching valve, pressure regulator, porous plug, and a high voltage isolator.

The ion source uses a Penning-type discharge from which positive xenon ions are extracted and accelerated electrostatically.

The cathode of the discharge is a porous tungsten insert, impregnated with low work function producing oxides. An axial magnetic field is used to restrict electron flow radially and increase the number of electron-atom collisions. External to the ion accelerating grids is a neutralizer heater which can be operated in a controlled loop mode to emit approximately the same magnitude of electron current as that of the ion beam for neutralization of the beam. Emission is adjusted by varying the temperature of the heater.

The characteristics of the positive Ion Beam System are shown in Table 1. A list of commands available in the instru-

ment is shown in Table 2. Those commands used only for automatic programming in flight as well as those wired to the ground test umbilical connector are indicated. A list of telemetry analog outputs is shown in Table 3. All telemetry outputs from the Positive Ion Beam System were given main frame word assignments in the PCM system, to be described later, except the expellant tank pressure monitor and the power processor assembly temperature.

2.1.3 Launch Tower Initialization and Flight Program for the Positive Ion Beam System

"Many minutes are required to activate the PIBS cathode, start a discharge and extract a beam. Therefore, prior to launch the ionization chamber must be evacuated, the cathode activated, and a discharge struck and maintained. Then the vehicle must be launched in a discharge mode until at proper altitude the positive ion beam cap is removed and automatic program takes over for beam operation.

This ground initialization procedure requires the flow of expellant gas and therefore precludes the use of a light, on board, vacuum system. A portable vacuum system operable prior to launch in the launch tower was designed and built by Ken McGee of AFGL. It consisted of an oil piston fore pump and a turbo-jet high vacuum pump. An ionization gauge vacuum monitor was used.

Pre-launch start-up of the Positive Ion Beam System requires the following sequence of operations.

(1) Prior to T-one hour the nose cone of the payload is removed and the portable pumping station is moved near the payload and connected to the pump-out port of the ion source blow-off cover. The ion source is evacuated to a pressure of 10^{-5} torr or better.

(2) At T-one hour the PIBS command simulator is connected to the PIBS test umbilical connector and the initialization commands (without instrument power on) are given: 7,8,10,13,16,19, 20,23,28. (See Table 2). The PIBS is turned on by control in the blockhouse throughland lines connected to another umbilical connector.

(3) Command 3 is given and after five seconds, command 4 is given. This allows sufficient expellant gas to be entered into the front end of the pressure regulator (at 900 to 1000 psi) to operate the PIBS for 2 1/2 to 3 hours. At this time the ionization gauge in the launch tower rises to 2 to 5×10^{-4} torr because of the xenon gas flow.

(4) Command 5 is given, applying about 25 watts of power to the cathode heater and turning on the discharge supply within the PIBS.

(5) Commands 6, 10 and 28 are given in rapid succession. Command 6 turns on the ion gun power, including the keeper, beam and accel supplies. Command 10 removes the keeper power, and command 28 removes the beam and accel power. At this point a discharge should be struck as indicated by analog monitors, 3 and 8.

At T-30 minutes the pump port on the ionization chamber of the PIBS is closed, the vacuum system stowed away from the payload, and the nose cone mounted in place. The PIBS command umbilical cord is removed and the instrument is ready for final countdown and flight.

At the proper altitude power is applied to a relay driver card allowing the command program to be entered into the PIBS, and to the high power mode relay in the EBS. The automatic command sequence is shown in Table 4.

Prior to the application of program power the PIBS ion gun power is off and there is therefore no beam voltage, nor can the neutralizer filament and neutralizer bias supply be turned on.

The electron gun at this time can operate properly in modes 9 and 10 but the high current and high voltage relays cannot be pulled in until the application of program power. Mode number 11 therefore can only enable the EBS to emit 13 milliamperes at 1.5 kilovolts.

Each mode lasts one-half second. A mode cycle is therefore six seconds long. With the application of program power from the experiment timer, the PIBS starts to operate at the time of the next M_1 signal, when PIBS command No. 6 is issued.

2.2 Instrument Programmer

An instrument programmer was required to establish a mode sequence for the particle beam systems and also to set some of the measurement instrument paramaters as a function of mode.

For each mode of the particle guns, the Retarding Potential Analyzer is stepped through six levels of analysis. The gain of the outer thermal emissive probes must be changed as a function of particle polarity. The Inter-Segment voltmeter must change pre-amplifier gain and impedance level in anticipation of transients at each mode change. The camera shutter must be advanced at each mode change and be given binary coded decimal digital information for recording of mode and mode sequence count on each picture frame for correlation of camera recorded events with experiment program.

2.2.1 Programmer Circuit Description

The instrument program requires two circuit boards in the instrument electronics box located in the un-pressurized electronics section. The schematics are shown on Drawings D-876 and D-874.

U_1 of Drawing D-876 is a 24 Hz oscillator. U_2 is a divide-by-twelve counter. The first stage output is Q_o and is a square wave at 12 Hz. This is the basic time interval required for the six steps per mode for the Retarding Potential Analyzer.

The last three stages of U_2 can be considered a divide-by-six counter with weights of 1, 2 and 3 for Q_1, Q_2 and Q_3 outputs.

U_5 is a 1 of 8 decoder/demultiplexer which converts the divide-by-six outputs to 1 of 6 outputs, down. U_8 is a hex inverter producing the R_1 through R_6, one-of-six, up, signals for the Retarding Potential Analyzer. Table 5 shows the count in the last three stages of U_2 versus the outputs of U_2 and of U_5.

The output of the last stage of U_2, A_3 is a square wave at 2 Hz. This is the basic time interval for each mode of the twelve step program. This output is counted in the divide-by-twelve counter U_4, on Drawing D-874.

It should be noted here that the circuits of U_1, U_3, U_7, U_8, U_9, U_{10}, and U_{11} were used in the original programmer design to provide variable mode lengths in modes 4 and 8. These were the modes when the neutralizer filament was originally turned on and off. The on-off thermal time constants of the filaments were not known at that time so provision was made to pre-wire extended

modes in one-half second increments in both Mode 4 and Mode 8. These delays were by-passed in the flight configuration since the thermal time constants involved were found to be insignificant relative to the final program design.

The outputs of U_4 are returned to Mode Signal Generator on Schematic D-876 and are fed to U_6 and U_7 forming a one-of-twelve, down circuit. U_9 and U_{10} invert these outputs to produce positive gates for use in the Retarding Potential Analyzer. Table 6 shows the count in the Mode counter versus the counter and decoder outputs.

U_{13} generates a high signal when in modes 1 through 8 (PIBS ON). This signal is used to reduce the gain of the outer Thermal Missive Probes on the booms, when the ion beam is on.

The logic of the gates in U_{12} produces a positive gate, $\triangle$ M, which brackets each mode change. This resulting gate is present from approximately 20 milliseconds before until 20 milliseconds after every mode change. This gate is used to change the gain and impedance of the intersegment bi-polar voltmeter and to reset and look for peak transients out of the bi-polar volmeter just after mode change.

The circuit of U_3 is used to generate a six step staircase representing the A_1 , A_2, and A_3 counter (retarding voltage step) for telemetry.

The circuit of U_4 is used to generate a twelve step staircase representing the mode counter (B_o, B_1, B_2, B_3 outputs) for telemetry.

On schematic D-874, U_5 and U_6 are divide-by-sixteen counters which count the number of twelve step mode cycles. They are capable of accummulating 256 mode cycles representing 1536 seconds or 25.6 minutes of payload operation. The outputs of the U_5 and U_6 counters are summed in binary weighted resistor matrices to produce two sixteen step staircases, P_1 and P_2 for telemetry.

The outputs of the U_4, U_5, and U_6 counters are also sent to the camera electronics. Transitions of B_o (least significant bit of the mode counter) are used in the camera electronics to trigger the camera shutter, once every one-half second or every mode change. All bits of the three counters are used for generation of decimal digits in the camera display unit which provides a coded frame number.

for each picture frame taken. A description of the codes and correlation with the mode and program staircases is described later in this report.

2.3 Retarding Potential Analyzer

The RPA experiment is made up of three components. Two are sensor packages each with its own self contained bi-polar logarithmic amplifier and the third is the common electronics package. Each sensor is mounted with its acceptance axis perpendicular to the vehicle axis and at 90 degrees from the other sensor.

2.3.1 Sensor Description

The sensors are identical. An assembly drawing for them is shown in Drawing C-428. Each sensor consists of four elements. One is a one inch aperture with two tungsten mesh grids spaced 0.15 inches apart and having an optical throughput of 0.8. The aperture is made a double grid in order to minimize electrostatic punch-through of the retarding voltage from affecting the environment just outside the sensor. The retarding grid is 0.5 inches behind the aperture and its optical through-put is 0.90. The auxiliary grid of two meshes 0.15 inches apart and 0.5 inches from the retarding grid. The total through-put of all the grids is 0.60.

This auxiliary grid is double in order to minimize the capacitance between the retarding grid and the collector and thereby minimizing the displacement current to the input of the logarithmic amplifier due to the huge voltage steps (2000 V applied to the retarding grid). The collector or cathode is a stainless steel plate 0.15 inches behind the auxiliary grid.

The voltages on aperture, retarding and auxiliary grids for each sensor are developed from common circuits. The collector potential is established at ground by reference voltages of two seperate operational amplifiers. The aperture grids are always at + 2.0 V and the collector at zero with respect to the vehicle potential. The retarding and auxiliary grid voltages are programmed in modes M_1 through M_{12} and steps R_1 through R_6 as shown in Table 7. The auxiliary grid is made -15 volts to minimize secondary electrons from leaving the collector when high energy particles are imposing on it. The grid is made zero volts whenever its -15 volt potential can contribute to that being applied to the retarding grid.

2.3.2 The Bi-Polar Logarithmic Amplifier

The bi-polar logarithmic amplifiers are designed to measure the net charged particles collected on the cathode element of the RPA sensors. The amplifiers for each sensor package are identical. Calibration data in the form of five decade curves is given in Figure 1. The amplifier output voltage for zero input current is 2.40 volts. For input currents less than 10^{-10} amperes the curve is approximately linear. For input currents greater than 10^{-10} amperes the curve is logarithmic with a slope of 0.5 volts per decade increasing for positive currents and decreasing for negative currents. The output is limited by semiconductors from going below -0.5 V or above +5.5 volts.

The schematic for the bi-polar logarithmic amplifiers is shown in Drawing C-896. It consists of a high input impedance (low leakage) operational amplifier, U_1 an ICH 8500A, two logging circuits, the main elements for which are the PNP transistor Q_1 for negative input currents and the NPN transistor Q_2 for positive input currents, and the signal conditioning amplifier U_2. The input and output of U_1 are designed to be at zero volts for zero input

current. The feedback betas (determined by R_7, R_8, R_9, R_{10} for the negative logging circuit) and by R_{11}, R_{12}, R_{13}, R_{14} for the positive logging circuit) operating on the natural log characteristic of Q_2 and Q_4 of 60 mv per decade of input current results in output change of 0.70 volts per decade above and below zero volts. The operational amplifier U_2 is used to offset the zero to approximately +2.5 volts and set the gain to 0.5 volts per decade to give approximately ± 5 decades of dynamic gain between 0 and +5.0 volts. Resistors R_8 and R_{12} in the feedback beta networks have temperature coefficiently, of 0.75%/^{o}C to compensate for the temperature coefficient of the semiconductor logarithmic slope characteristics. The displacement current to the input of the amplifier from the voltage switching waveforms on the retarding and auxiliary grids coupled through their respective capacitors to the cathode is cancelled by applying a sample of the reciprical of these waveforms through capacitor C_3. The voltage transient from the auxiliary grid is the order of 15 volts through 20 pf and that on the retarding grid the order of 2000 volts through 0.02 pf. The resultant displacement current is about 10^{-10} amperes and with a duration of less than 0.2 seconds.

2.3.3 The RPA Electronics Package

The electronics package consists of Mode and Range Logic, Relay Circuits, a High Voltage Power Supply, a Low Voltage Analog Multiplexer, and Signal Conditioning Circuits for the retarding grid, auxiliary grid, telemetry monitors and displacement current amplifier. The schematics for the electronics package are shown in Drawings C-899 and D-900.

The retarding grid voltage stepping philosophy is easily demonstrated in Drawing C-899. There are two stepping voltage ladders generated. One is referred to as a High Voltage Ladder used in Modes 1-2-3-4-6-7-9-10-11 and the other is the Low Voltage Ladder used in Modes 5-8-12. The selection is made by energizing relay K_1 for the High Voltage Ladder or K_2 for the Low Voltage Ladder. The High Voltage Ladder is generated by properly energizing high voltage reed relays K_3 through K_{13}. The Low Voltage Ladder is generated (D-900) by properly gating the analog multiplexer U_{11} and level changing operational amplifier $U_{12}B$.

The High Voltage Ladder as shown in Table 7 must be able to go from +2000 to -2000 volts as function of Mode and Range. The polarity selection is accomplished by relays K_{10} through K_{13}. If K_{10} and K_{13} are closed contact K_{13} grounds the negative terminal of the high voltage power supply and K_{10} contact connects the positive terminal to the input of the range relays K_3 through K_9.

The minus polarity ladder is generated by closing relays K_{11} and K_{12}. For both polarity ladders there are basiclly two levels -1000 volts and 2000 volts. With K_9 unenergized resistor R_2 is made part of the range divider and the highest voltage available at K_3 is $\pm$ 1000 volts. With K_9 energized R_2 is shorted out and the full 2000 volts is available at K_3. The resistor divider R_3 through R_8 makes available voltages which are related to those above and below by factors of approximately three.

The logic performed for energizing each relay as a function of Mode and Range is as follows:

Hi or Lo Voltage

$$K_1=\bar{K}_2 = M_1+M_2+M_3+M_4+M_6+M_7+M_9+M_{10}+M_{11}$$

$$= \overline{M_5+M_8+M_{12}}$$

Magnitude

$K_9=M_3+M_9+M_{10}+M_{11}+M_6(R_4+R_5+R_6)$

Polarity Positive

$(K_{10})(K_{13})=M_1+M_2+M_3+M_4+M_7+M_6(R_4+R_5+R_6)$

Polarity Negative

$(K_1)(K_{12})=M_9+M_{10}+M_{11}+M_6(R_1+R_2+R_3)$

Range Relays

$K_8=R_1(M_1+M_2+M_3+M_4+M_7+M_9+M_{10}+M_{11})$

$K_7=R_2(M_1+M_2+M_3+M_4+M_7+M_9+M_{10}+M_{11})$

$K_6=R_3(M_1+M_2+M_3+M_4+M_7+M_9+M_{10}+M_{11}+M_6)+M_6\ R_4$

$K_5=R_4(M_1+M_2+M_3+M_4+M_7+M_9+M_{10}+M_{11})\ +M_6\ R_5+M_6+R_2$

$K_4=R_5(M_1+M_2+M_3+M_4+M_7+M_9+M_{10}+M_{11})$

$K_3=R_6(M_1+M_2+M_3+M_4+M_7+M_9+M_{10}+M_{11}+M_6)\ +M_6\ R_1$

The Low Voltage Ladder is generated by a analog multiplexer U_{11} as shown in Drawing D-900. The BCD signals A_1, A_2, and A_3 which represent the Range Logic before decoding are used to gate the appropriate voltage established by the resistor divider R_{21} through R_{31}. This voltage is then conditioned by the operational amplifier $U_{12}B$ to obtain the ladders required in Modes 5, 8, and 12.

The logic for auxiliary grid voltage if zero or -15 volts is given by:

$V_o(-15)=(R_4+R_5+R_6)(M_1+M_2+M_3+M_4+M_7+M_9+M_{10}+M_{11})+M_6$

It is generated by turning off Q_{12} for the above conditions.

The displacement current cancellation waveform is developed by appropriately summing V_o and V_R through R_{40} and R_{60} and inverting through the operational amplifier U_{12} A.

2.4 Thermal Emission Probes

The TEP experiments were designed to measure the environment to spacecraft potential difference. This measurement is accomplished by floating (isolating by a known impedance) a collecting sphere and an emitting filament with the expectation that sphere and filament will remain at environment potential.

The charging rocket experiment used four TEP's mounted on two (2) booms. One (1) boom was designed to measure $\pm$ 300 volts and the other $\pm$ 500 volts.

2.4.1 Circuit Description And Calibrations

The TEP electronics consisted of:

(a) Preamplifier
(b) Shield Drive Amplifier
(c) DC to DC converter
(d) Telemetry Amplifiers

Drawing D-906 is a schematic of the TEP electronics. The preamplifier was designed around a high impedance operational amplifier manufactured by Analog Devices. The input and feed back resistors differed for each of the four (4) probes.

The two (2) outer probes also had a resistor relay circuit for changing the amplifier gain as a function of mode. The gain change allowed the outer sensors on each boom to measure peak voltages to ± 1000 volts without exceeding the telemetry limits of the post amplifiers.

The request for an extended range as a function of mode was made after fabrication had started. A compromise in the performance was agreed upon that only required the sensors to have a ± 1000 volt range but not the shield drive amplifier.

To reach ± 1000 volts with the shield drive amplifiers would require new amplifier design and higher voltage power supplies.

The shield drive amplifier was driven from the output of the preamplifier and provided a voltage that tracked the filament and sphere.

The shield consisted of a brass tube which was used to support the sensors. The shield was biased about 10 volts negative with respect to the filaments so that emission from the filament to the shield would not occur. The resistors used for gain selection were manufactured by Victoreen Inc. (type MOX 1125) and were selected for their voltage coefficient of resistance.

The DC to DC converter supplied the power to the tungsten filaments by way of isolation transformers T_5 and T_6. The isolation transformers were carefully wound so that the impedance from winding to winding would not shunt the input impedance of the preamplifier. The input resistor of the 300 volt amplifiers U_8 3×10^{10} ohms and for the 500 volt amplifiers is 10^9 ohms. Transformers T_3 and T_4 were used to give an indication of heating current supplied to the filament and serve as a monitor for a broken or open filament.

The post amplifiers used for each TEP are shown schematically on Drawing C-875. U_1, U_2, and U_3 are parallel linear amplifiers with circuit gains of +12.55, + 2.5, and +0.5 volts per volt. The output maximum swings of the amplifiers are $\pm$ 5 volts. Therefore, U_1 limits at $\pm$ .4 volts in, U_2 limits at $\pm$ 2.0 volts in and U_3 limits at $\pm$ 10 volts in (the limit of the preamplifier output).

Point A is wired to point D, point B to E, and point C to F. U_4, U_5, and U_6 are identical amplifiers with gains of -0.5 volts per volt and with a +2.5 volt output zero offset. The resulting combination provides three successively limiting outputs to telemetry with adjacent channel gain ratios of 5. With zero input, all three outputs are at +2.5 volts. With +0.4 volts out of the preamp, the U_4 output is at full scale, or zero volts, U_5 at +2.0 volts and U_6 at +2.4 volts.

Calibration for the TEP's was performed at AFGL during the month of June 1977. The tests were conducted in a bell jar which was evacuated to about 10^{-5} torr.

An auxiliary filament and sphere, which were controlled by external power supplies, were varied over the desired range for each sensor element. As the input from the preamplifier increases in a positive direction to 2.0 volts, the output of U_4 is saturated at zero volts, U_5 goes to zero volts, and U_6 goes to + 2.3 volts. At + 10 volts in, U_4 and U_5 are saturated and U_6 just reaches full scale of zero volts.

Opposite polarity inputs cause the outputs to successively saturate at + 5.0 volts for - 0.4 volts, -2.0 volts, and - 10 volts respectively.

An additional test was performed to see if any problems occur when a new filament is used to replace an old or broken one. It is necessary to know how long it takes for a new filament to reach peak emission because of the relatively short time of flight of the rocket. A typical test result appears on Table

2.5 Inter-Segment Bi-Polar Amplifier

The Inter-Segment Bi-Polar Amplifier was used to measure the potential difference between a relatively large collecting area and the main payload body. The recovery parachute housing was used as the collecting area, insulated from the payload by means of a machined epoxy glass ring.

The high impedance voltmeter schematic is shown on Drawing C-946. The floating housing is connected to the 10^9 ohm resistor at the amplifier input. For steady state operation (from 20 milliseconds after a mode change until 20 milliseconds before the next mode change), relays K_1 and K_2 are not energized and R_1 and R_3 are out of the circuit. The overall preamplifier gain is .01 volts/volt. For a $\pm$ 10 volt output swing the floating element can swing $\pm$ 1000 volts.

During the mode change interval of 40 milliseconds. K_1 and K_2 are energized, reducing the input resistor to 10^6 ohm and the amplifier gain to 0.1 volts/volt. For a $\pm$ 10 volt output swing the floating element can swing $\pm$ 100 volts. The reduced impedances in the amplifier provide an overall amplifier frequency response of over 200 KH_z when driving the input with a voltage source.

The output of the preamplifier is fed to a telemetry triad identical to those used in the thermal emissive passive probes, and positive and negative peak detectors. The detectors sample during the 40 millisecond mode change interval and hold for the remainder of the mode.

The schematic for the peak detectors is on Drawing C-916. U_1 and U_2 form the peak detector and sample and hold. The negative peak detector is identical to the positive peak detector except for the polarity of diodes CR_1 and CR_2, and the use of inverting amplifier U_5 which is used to reverse the polarity of the output signal for compatability with the PCM telemetry system.

As the timing table on the schematic shows, during the first second of the mode change interval, S_2 and S_3 are closed. (These field effect transistor switches are part

of the analog multiplexer U_3). This causes the hold capacitor, C_2, to be set to zero volts.

During the next 39 milliseconds, the S_1 is closed and S_2 and S_3 are open. The output follows the input, positive or negative depending upon the polarity of CR_1 and CR_2. Capacitor C_2 maintains a voltage equal to the largest peak seen during this interval. The output then follows this voltage.

During the next 460 milliseconds, switch S_1 opens and the output remains at the peak voltage held by capacitor C_2. The reset, peak detect, and hold operation repeats itself at the next mode change signal.

2.6 Camera Electrical Interface

The camera system was designed and built by Photometrics, Inc., of Lexington, Mass. a boom-mounted mirror system allows the camera to look forward along the skin of the payload, and at a set of spaced electrodes imbedded in the insulating ring between the payload electronics section and the parachute housing.

The camera also provides an eight decimal digit display for recording film frame number. The twelve bits from the programmer mode and program counter are provided to the camera electronics. The least significant bit of the mode counter which changes every mode change is used to advance the film and operate the camera shutter. All twelve bits are used in the binary-coded-decimal to seven segment display decoder.

Table 16 shows the frame encoding used for the Binary-coded-decimal camera display. Decimal digit D_1 has six states, 0 through 5. D_3 and D_5 have eight states, 0 through 7. D_2, D_4, and D_6 have two states each, 0 through 1.

D_1 and D_2 are then the mode counter with a maximum count of 12. D_3 through D_6 represent the program count with a maximum count of 256.

The actual film display is shown at the bottom of Table 16. The arrows indicate carries.

The camera decoder logic and film and shutter advance electronics are all TTL compatible. The + 5 volt power for the camera electronics is supplied by the same regulated supply as that used in the programmer, RPA, subcommutators, and telemetry postamplifiers.

The camera shutter and film advance requires 10 to 20 ampere pulses at 28 volts. Since this power is not needed until after all doors are opened and booms deployed, the battery for the timers, and electro-explosive devices for door, tip and boom deployment are switched over to the camera after all other timed events occur. This provides a dedicated battery supply to the camera and prevents power line cross talk between camera and experiments due to film and shutter advance current pulses.

2.7 Telemetry PCM Format

Table 17 shows the PCM format and word assignments. There is a 32 word main frame with 11 bits per word, 10 bits data and the most significant bit is used for odd parity. The bit rate is 220,000 per second producing a main frame rate of 625 per second. The PCM unit is a Model Number HC11EM-2261 made by Fifth Dimension, Inc., of Princeton, New Jersey. It provides two internal sub-commutators. The "B" internal sub-commutator used main frame word Number 16 and is twenty words long, one word of which is used as a "B" sub-commutator sync word. The "C" internal sub-commutator is five words long, one word of which is used as a "C" sub-commutator sync word.

Because 90 monitor functions were required, many of which were slow moving channels, two external sub-commutators were built into the electronics section of the un-pressurized section. The schematic for one external sub-commutator is shown on Drawing D-905.

U_1 is a seven stage binary counter of which five stages are used and arranged such that on the beginning of count 20, the counter is reset to zero. The counter counts main frame sync pulses available from the PCM system. A sub-commutator sync signal is also available from the PCM system. Therefore, the "D" and "E" external sub-commutators are locked in step with the "B" internal sub-commutator. This allows ground PCM decommutators to extract external sub-commutator signals by using the "B" sub-commutator code.

U_2, and U_3 and U_4 are one-of-eight multiplexers with inhibit lines, wired to form a one-of-twenty multiplexer. The Q_o, Q_1 and Q_2 outputs of the counter drive the binary control inputs A,B, and C of the multiplexers. The Q_3 and Q_4 outputs of the counter are logically combined in the first three positive nand gates of U_6 to drive the inhibit lines of the multiplexer.

The last gate of U_6, a negative nor gate, resets the counter either in the presence of a signal from U_7 on the count of 20 in the counter or a PCM sub-frame sync.

There are then, 20 input data lines and a single multiplexed output line. The "D" sub-commutator output is wired to main frame word Number 20 in the PCM. The "E" sub-commutator output is wired to main frame word Number 29.

The PIBS system was given highest priority. This instrument had never been flown and the charging Rocket A31.603 was the first attempt to obtain space flight operation information prior to the SCATHA satellite flight for which the basic instrument was originally designed. The PIBS was especially involved because of the complexity of the gas supply, heating of the cathode, start of the discharge, pressure rise in the ionization chamber after closing the pump port, and the squib operated cover release. Therefore, the PIBS monitors (all except the xenon tank pressure and power processor assembly temperature) were assigned to the high speed main frame. These are main frame words, 1 through 14 inclusive and words 18, 19, and 21. In the final program design word 21 always indicated negative neutralizer polarity.

The REBS cap and frame current monitors were assigned main frame word Numbers 27 and 28. Words 15 and 16 were used for the 12 step mode staircase and the 6 step RPA staircase generated in the programmer section of the electronics. The RPA logarithmic electrometer outputs were assigned words 22 and 23. The RPA analog staircase outputs were assigned words 25 and 26. A Squib system monitors were assigned words 30 and 31.

The "B" internal sub-commutator carried the 12 TEP outputs and the door, caps, boom and tip monitors as well as all battery monitors.

The "C" internal sub-commutator carried the X and Y magnetometers and accelerometer outputs.

The "D" external sub-commutator carried the Aerospace Surface Potential Monitor outputs, the Stanford Research Institute Transient Pulse Monitor outputs, a camera shutter motion monitor and the Bi-polar Voltmeter outputs.

The "E" external sub-commutator carried all the regulated supply monitors, pressure and temperature monitors, program staircase monitors and the TEP filament current monitors.

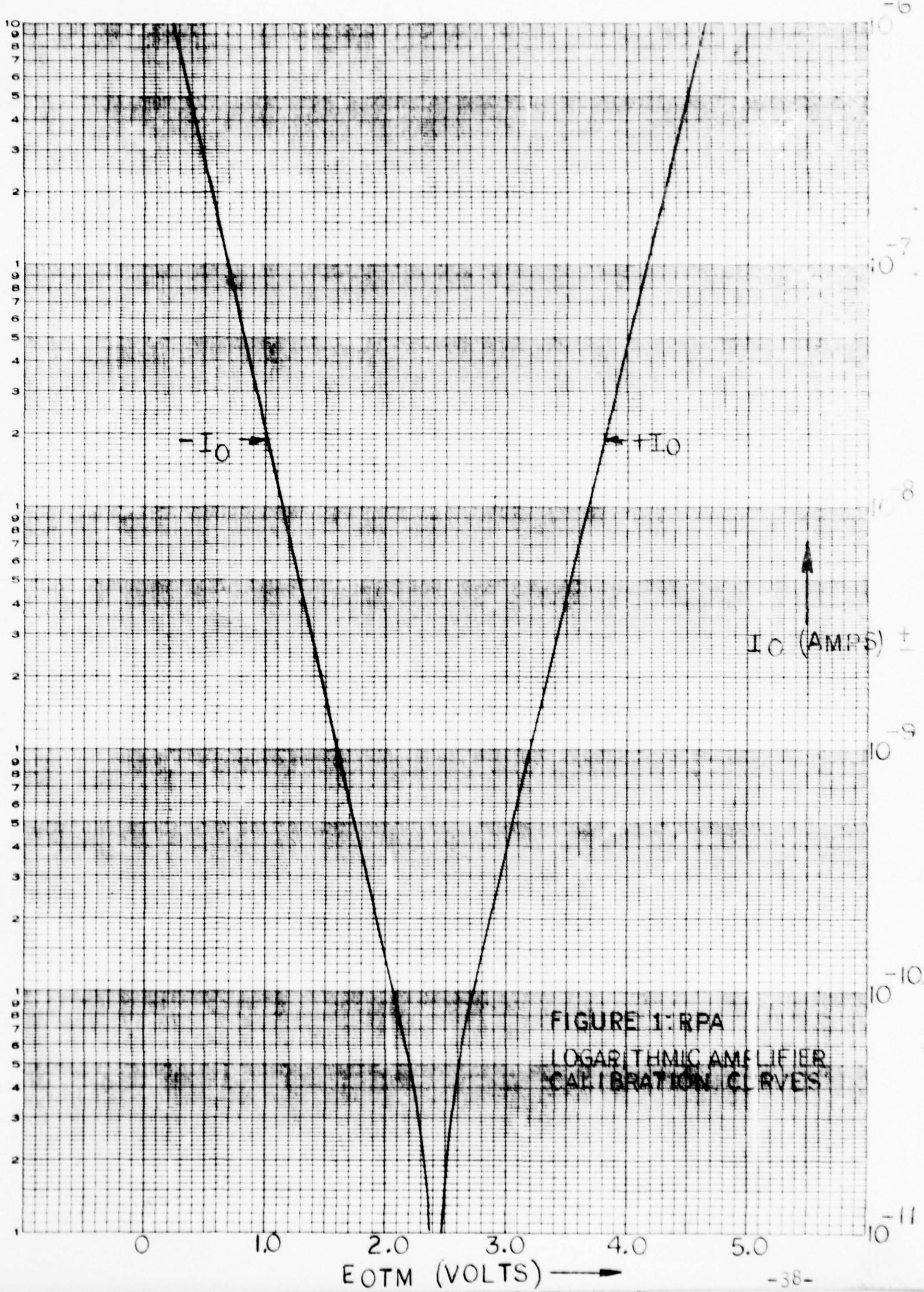


FIGURE 1: RPA LOGARITHMIC AMPLIFIER CALIBRATION CURVES

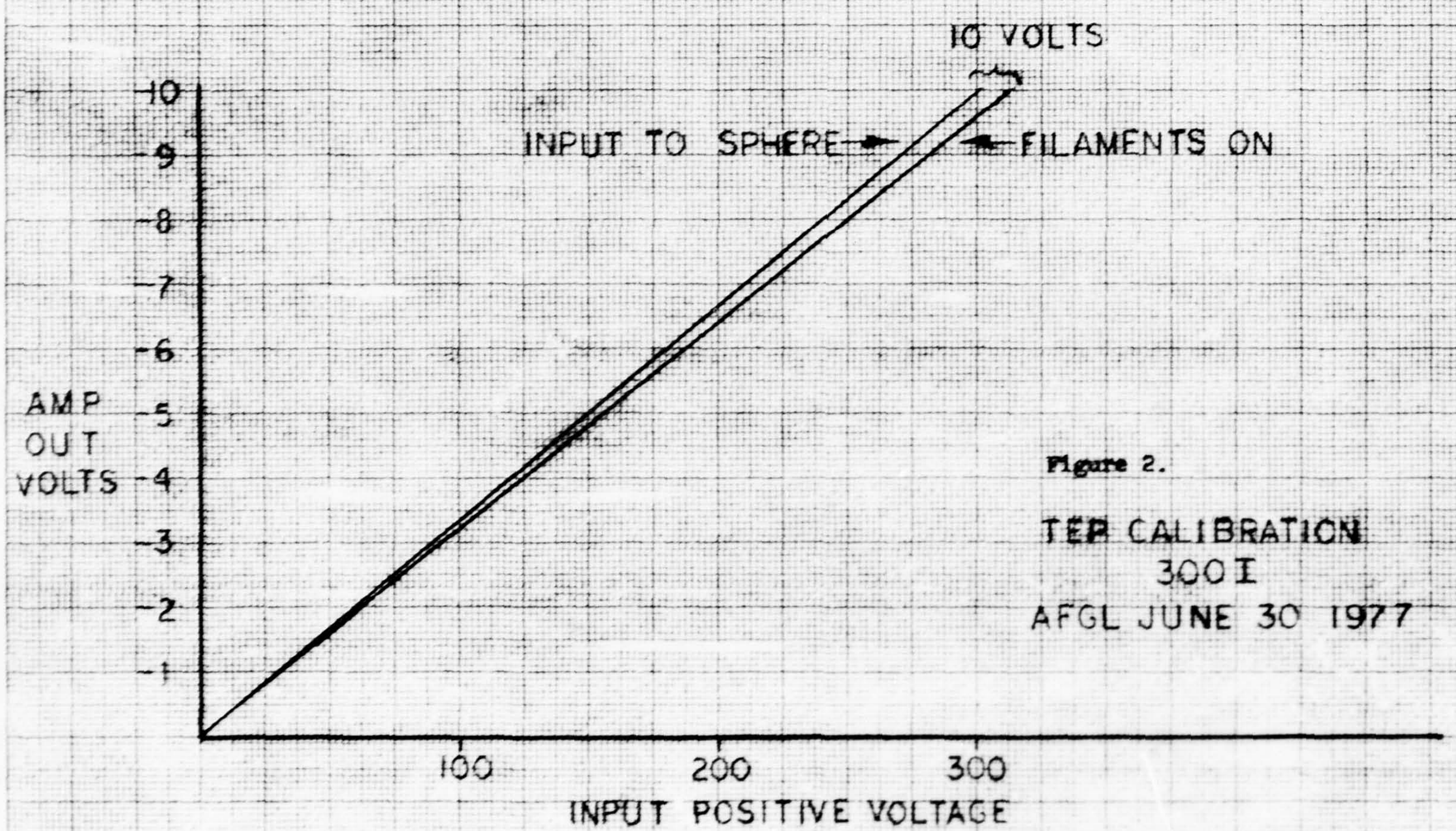


Figure 2.

TEP CALIBRATION
300I
AFGL JUNE 30 1977

10 X 10 TO THE CENTIMETER 46 1512
KEUFFEL & ESSER CO.

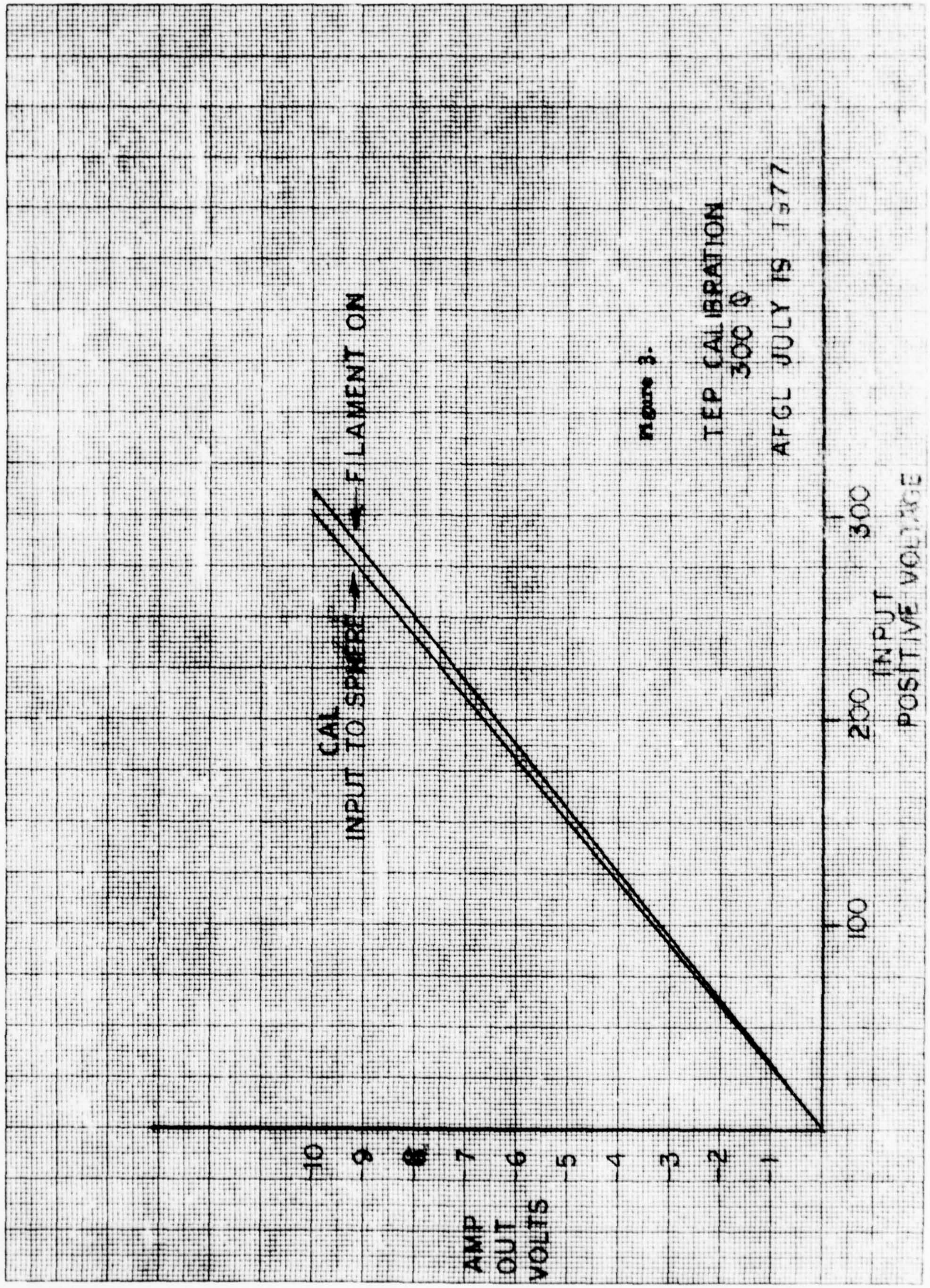


Figure 3.

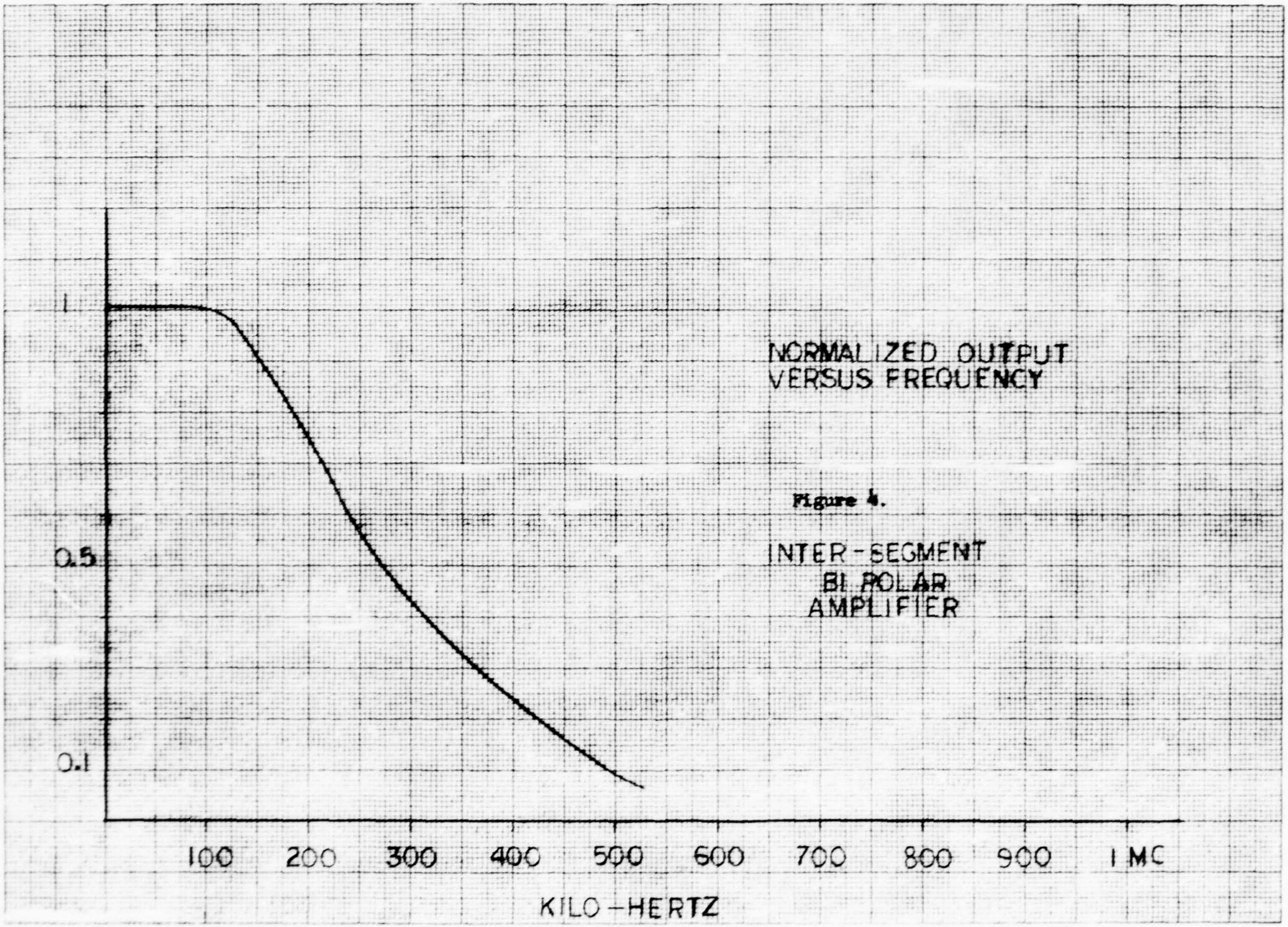

NORMALIZED OUTPUT
VERSUS FREQUENCY
INTER-SEGMENT
BI POLAR
AMPLIFIER
1
0.5
0.1
100
200
300
400
500
600
700
800
900
1 MC
KILO-HERTZ

Figure 4.

TABLE 1. Positive Ion Beam System Characteristics

ELECTRICAL		
1.	Ion beam current, mA	0.3 to 2.0
2.	Ion beam energy, eV	1000 and 2000
3.	Input voltage, V	24 to 32
4.	Input power, W	
	a. Maximum startup	50
	b. Beam of 1 mA and 1 kV	25
	c. Beam of 2 mA and 2 kV	45
	d. Full beam and biased neutralizer	60
5.	Discharge current, mA	30 to 200
6.	Discharge voltage, V	25 to 35
7.	Cathode power, W	0 to 25
8.	Keeper power, W	2
9.	Neutralizer heater power, W	0 to 8
10.	Neutralizer bias voltage, V	0 to 1000
11.	Accelerator voltage, V	-150 to -300
12.	Expellant latching valve, A/V/mS	
	a. Opening	1.0/23/50
	b. Closing	0.1/28/50
DATA AND COMMAND		
1.	Commands	
	a. Number	Up to 29
	b. Voltage level, V	29
2.	Analog Outputs (Telemetry)	
	a. Number	Up to 18
	b. Voltage range, V	0 to 5
PHYSICAL		
1.	Weight, kg (lb)	7.3 (16.0)
2.	Size, cm	49 x 23 x 13

TABLE 2. Positive Ion Beam System

G	F	Command	Function
		1. Instrument on*	Turns on instrument power
		2. Instrument off*	Turns off all instrument power
x		3. Expellant valve open	Opens solenoid valve
x		4. Expellant valve closed	Closes solenoid valve
x		5. Cathode heater preheat	Turns on the cathode heater to Level 1 and turns on discharge supply
x	x	6. Ion gun power on	Turns on the ion gun power
x		7. Ion gun power off	Turns off the ion gun power
x	x	8. Beam voltage Level 1	Sets the beam power supply to 1000 V
x	x	9. Beam voltage Level 2	Sets the beam power supply to 2000 V
x		10. Keeper off	Turns the keeper supply off
x		11. Discharge current and neutralizer emission Level 1	Sets the discharge current reference to achieve 20 mA Current: sets neutralizer emission level to 0.4 mA
x	x	12. Discharge current and neutralizer emission Level 2	Sets the discharge current reference to achieve 125 mA: sets neutralizer emission Level to 1.2 mA
x	x	13. Discharge current and neutralizer emission Level 3	Sets the discharge current reference to achieve 200 mA: sets neutralizer emission level to 2.2 mA
		14. Neutralizer emission Level 4	Sets neutralizer emission level to uA
		15. Neutralizer emission Level 5	Sets neutralizer emission level to 20 uA
x		16. Neutralizer No. 1	Selects neutralizer filament No. 1
		17. Neutralizer No. 2	Selects neutralizer filament No. 2
x	x	18. Neutralizer heater on	Turns on the neutralizer cathode heater on
x	x	19. Neutralizer heater off	Turns off the neutralizer heater
x		20. Neutralizer bias off	Turns off the neutralizer bias power supply
x		21. Neutralizer bias positive	Sets the neutralizer bias for positive polarity
x		22. Neutralizer bias negative	Sets the neutralizer bias for negative polarity
x	x	23. Neutralizer bias Level 1	Turns on the neutralizer bias to 10 V
		24. Neutralizer bias Level 2	Turns on the neutralizer bias to 25 V
		25. Neutralizer bias Level 3	Turns on the neutralizer bias to 100 V
		26. Neutralizer bias Level 4	Turns on the neutralizer bias to 500 V
x	x	27. Neutralizer bias Level 5	Turns on the neutralizer bias to 1000 V
x	x	28. High voltage off	Turns off the beam and accel power supplies
x		29. Cathode conditioning	Turns on the cathode heater to Level 2

* "Instrument on/off" is implemented by connecting or disconnecting 28 V input power.

G-Commands Wired to Ground Test Umbilical Connector
F-Commands Issued Automatically During Flight Operation

TABLE 3. Positive Ion Beam System Analog Outputs (Telemetry) and Actual Value For Full Scale (5 V)

Channel No.	Description	Actual Value for 5 V Output, ± 5%
1	Beam current	2.5 mA (± 2%)
2	Beam voltage	2500 V
3	Discharge current	250 mA
4	Discharge voltage	50 V
5	Keeper current	250 mA
6	Keeper high voltage	1000 V
7	Keeper low voltage	50 V
8	Cathode heater current	5 A
9	Accel current[a]	2.5 mA
10	Decel current[a]	2.5 mA
11	Neutralizer heater current	5 A
12	Neutralizer bias voltage	1000 V
13	Neutralizer emission[b]	2.5 mA (± 10%)
14	SPIBS net current[b]	2.5 mA (± 10%)
15	Tank pressure	1500 psia
16	Power processor temperature	See calib curve
17	PPA AC inverter current	1.5 A
18	PPA AC inverter voltage	50 V

[a] To indicate anomolous condition

[b] In three ranges: 2.5 to 25 uA; 25 uA to 250 uA; 250 uA to 2.5 mA

TABLE 4. Particle Beam Systems Flight Mode Program Sequence

	MODE	CMDS ISSUED AT MODE START	BEAM CURRENT MAGNITUDE	BEAM VOLTAGE MAGNITUDE	NEUTRALIZER FILAMENT STATE	NEUTRALIZER BIAS VOLTAGE
Positive Ion Beam	M1	6, 12	1 mA	1 kV	Off	-10 V
	M2	None	1 mA	1 kV	Off	-10 V
	M3	13, 9	2 mA	2 kV	Off	-10 V
	M4	18	2 mA	2 kV	On	-10 V
	M5	None	2 mA	2 kV	On	-10 V
	M6	27	2 mA	2 kV	On	-1 kV
	M7	8, 19, 23	2 mA	1 kV	Off	-10 V
	M8	28	0	0	Off	-10 V
Electron Beam	M9	$M9\ \overline{M10}\ \overline{M11}$	1 mA	1.5 kV	Off	-10 V
	M10	$\overline{M9}\ M10\ \overline{M11}$	13 mA	1.5 kV	Off	-10 V
	M11	$\overline{M9}\ \overline{M10}\ M11$	35 mA	3 kV	Off	-10 V
	M12	$\overline{M9}\ \overline{M10}\ \overline{M11}$	0	0	Off	-10 V

TABLE 5. Count In Divide-By-Six Counter Versus Counter Outputs and One-of-Eight Decoder Used As One-of-Six

	Counter Outputs			1 of 8 Decoder Outputs					
Count	Q_3	Q_2	Q_1	$\bar{Q}_o$	$\bar{Q}_1$	$\bar{Q}_2$	$\bar{Q}_4$	$\bar{Q}_5$	$\bar{Q}_6$
0	0	0	0	L	H	H	H	H	H
1	0	0	1	H	L	H	H	H	H
2	0	1	0	H	H	L	H	H	H
3	1	0	0	H	H	H	L	H	H
4	1	0	1	H	H	H	H	L	H
5	1	1	0	H	H	H	H	H	L

TABLE 6. Mode Counter And Mode Signal Generator Outputs

Count	6 B_3	4 B_2	2 B_1	1 B_o	Only Output High
0	0	0	0	0	M_1
1	0	0	0	1	M_2
2	0	0	1	0	M_3
3	0	0	1	1	M_4
4	0	1	0	0	M_5
5	0	1	0	1	M_6
6	1	0	0	0	M_7
7	1	0	0	1	M_8
8	1	0	1	0	M_9
9	1	0	1	1	M_{10}
10	1	1	0	0	M_{11}
11	1	1	0	1	M_{12}

B_3 Used To Enable U_6 and Disable U_7 and Vice-Versa

B_o, B_1, B_2 Are weighted in Binary Fashion

RPA CAL DATA

EXP MODE / RPA MODE / RETARDING (V_R VOLTS) / AUXILIARY (V_O VOLTS)

EXP MODE	RPA MODE		R1	R2	R3	R4	R5	R6
M1	P	V_R	+1.7	+7.7	+25	+84	+254	+850
		V_O	0	0	0	−15	−15	−15
M2	P	V_R	+1.7	+7.7	+25	+84	+254	+850
		V_O	0	0	0	−15	−15	−15
M3	R	V_R	+3.5	+16	+51	+174	+527	+1760
		V_O	0	0	0	−15	−15	−15
M4	P	V_R	+1.7	+7.7	+25	+84	+254	+850
		V_O	0	0	0	−15	−15	−15
M5	S	V_R	−10.2	−2.8	+0.1	+2.9	+10.4	+22.3
		V_O	0	0	0	0	0	0
M6	T	V_R	−850	−84	−25	+51	+174	+1760
		V_O	−15	−15	−15	−15	−15	−15
M7	R	V_R	+1.7	+7.7	+25	+84	+254	+850
		V_O	0	0	0	−15	−15	−15
M8	U	V_R	+0.1	+0.6	+1.1	+2.0	+3.9	+10.4
		V_O	0	0	0	0	0	0
M9	W	V_R	−3.5	−16	−51	−174	−527	−1760
		V_O	0	0	0	−15	−15	−15
M10	W	V_R	−3.5	−16	−51	−174	−527	−1760
		V_O	0	0	0	−15	−15	−15
M11	W	V_R	−3.5	−16	−51	−174	−527	−1760
		V_O	0	0	0	−15	−15	−15
M12	U	V_R	+0.1	+0.6	+1.1	+2.0	+3.9	+10.4
		V_O	0	0	0	0	0	0

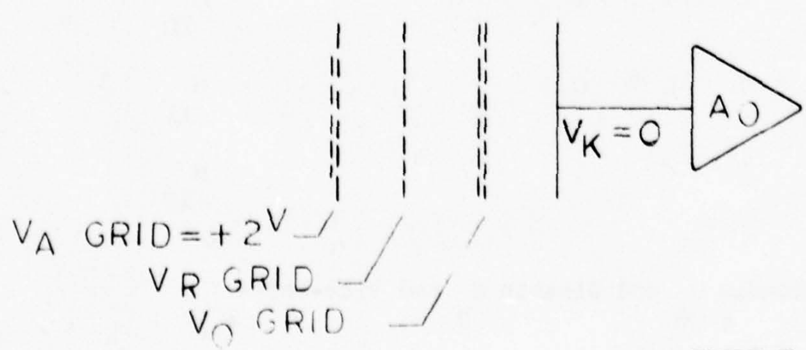


TABLE 7. Retarding Potential Analyzer Retarding Grid And Auxiliary Grid Calibration Data

TEP CALIBRATION TABLES

TABLE 8. 300 Volt Inner Thermal Emissive Probe Calibration

Input (Volts)	Output (Volts)			
	Preamplifier		Shield Amplifier	
	Direct Input To Sphere	Input to Test Filament In Proximity of Sphere	Direct Input To Sphere	Input To Test Filament In Proximity Of Sphere
+20	-.68	-.66	+12.2	+11.6
-20	+.64	+.69	-26.2	-27.3
+40	-1.34	-1.3	+31.5	+30.4
-40	+1.30	+1.3	-45.6	-46.1
+50	-1.67	-1.62	+41.2	+39.9
-50	+1.64	+1.60	-55.3	-55
+60	-2.0	-1.9	+50.8	+48.6
[illegible]	+1.96	+1.9	-64.9	-63.4
+80	-2.66	-2.6	+7.0	+67.9
-80	+2.62	+2.46	-84.3	-80.2
+100	-3.32	-3.23	+89.4	+86.5
-100	+3.27	3.2	-103	-95.4
+200	-6.6	-6.4	+185	+180
-200	+6.6	-6.5	-201	-193
+300	-9.9	-9.6	+282	+274
-300	+9.9	-9.6	-297	-285

TABLE 9. 300 Volt Outer Thermal Emissive Probe Calibration

Input (Volts)	Output (Volts)			
	Preamplifier		Shield Amplifier	
	Direct Input to Sphere	Input to Test Filament In Proximity of Sphere	Direct Input to Sphere	Input to Test Filament In Proximity of Sphere
+20	-.66	-.64	+11.5	+10.7
-20	+.65	+ 16	- 27	- 29
+40	-1.33	-1.3	+30.8	+25
-40	+1.32	+1.3	- 46	-47
+50	-1.65	-15.0	+40.4	+35.8
-50	+1.65	+1.74	-55.6	-58.6
+75	-2.49	-2.4	+64.6	+63
-75	+2.48	+2.4	-79.9	-83
+100	-3.3	-3.1	+88.6	+83
-100	+3.3	+3.3	- 104	-103
+150	-4.97	-4.8	+137	+133
-150	+4.95	+4.8	-152	-147
+200	-6.6	-6.5	+185	+183
-200	+6.6	+6.5	-200	-199
+300	-9.95	9.7	+281	+268
-300	+9.91	9.7	-297	-293

TABLE 10. 500 Volt Inner Thermal Emissive Probe Calibration

Input (Volts)	Output (Volts)			
	Preamplifier		Shield Amplifier	
	Direct Input to Sphere	Input to Test Filament In Proximity of Sphere	Direct Input to Sphere	Input to Test Filament In Proximity of Sphere
+25	-.51	-.32	+17.1	+7.1
-25	+.47	+.56	-32.6	- 36
+50	-1.0	-.78	+41.9	+30.4
-50	+.97	+1.04	-57.4	-61.5
+100	-2.0	-1.7	+91.6	+80
-100	+1.96	+2.0	- 107	-108
+150	-2.99	-2.6	+141	+123
-150	+2.95	+2.98	-156	-158
+200	-3.90	-3.63	+190	+175
-200	+3.94	+3.87	-206	-202
+250	+4.97	-4.54	+240	+218
-250	-4.93	+4.82	-255	-253
+300	+5.96	-5.63	+290	+270
-300	-5.92	+5.72	-305	-297
+350	+6.95	-6.4	+339	+315
-350	-6.92	+6.68	-355	-350
+400	+7.94	-7.45	+389	+367
-400	-7.91	+7.61	-405	-394
+450	+8.94	-8.41	+439	+417
-450	-8.90	+ 8.6	-454	-443
+500	+9.93	-9.4	+466	+464
-500	-9.89	+9.5	-504	-

TABLE 11. 500 Volt Outer Thermal Emissive Probe Calibration

Input (Volts)	Output (Volts)			
	Preamplifier		Shield Amplifier	
	Direct Input to Sphere	Input to Test Filament In Proximity of Sphere	Direct Input to Sphere	Input to Test Filament In Proximity of Sphere
+25	-.51	-.30	+16.7	+6.8
-25	+.481	+.55	-33.1	- 36
+50	-1.0	-.77	+41.6	+30.3
-50	+.97	+1.05	- 58	-61.5
+100	-1.99	-1.6	+91.4	+75.9
-100	+1.96	+2.0	-107	- 108
+150	-2.98	-2.61	+141	+123
-150	+2.95	+2.92	-157	-153
+200	-3.97	-3.56	+191	-172
-200	+3.94	+3.85	-207	-204
+250	-4.96	-4.52	+240	+217
-250	+4.93	+4.73	-257	-248
+300	-5.95	-5.46	+290	+266
-300	+5.92	+ 5.4	-306	-219
+350	-6.96	-6.4	+341	+313
-350	+6.93	+6.6	-357	- -
+400	-7.94	-7.36	+390	+360
-400	+7.91	+ -	-406	-
+500	-9.92	-9.26	+470	+457
-500	+9.89	+ -	-505	- -

TABLE 12.

New Filament Emission Test (July 20, 1977)
AFGL Bell Jar
Used 500 ϕ As A Power Source
Collector Biased At +50 V

TIME	FIL #1	FIL #2
5 SEC	4 uA	20 uA
15 "	14 "	24 "
30 "	22 "	27 "
45 "	30 "	31 "
60 "	34 "	35 "
90 "	40 "	40 "
120 "	44 "	44 "
3 MIN	49 "	49 "

TABLE 13. Inter-Segment BiPolar Voltmeter
Preamp Calibration

Fast Mode Low Impedance

E_{in}	E_{out}	E_{in}	E_{out}
10	1.04	60	6.26
20	2.08	70	7.30
30	3.12	80	8.35
40	4.17	90	9.41
50	5.21	100	10.47

High Voltage Mode

E_{in}		E_{out}	E_{in}		E_{out}
± 100	+.99	-.99	± 600	+5.96	-5.97
± 200	+1.99	-1.99	± 700	+6.96	-6.97
± 300	+2.98	-2.98	± 800	+7.95	-7.97
± 400	+3.97	-3.98	± 900	+8.95	-8.98
± 500	+4.97	-4.98	±1000	+9.95	-9.96

June 16, 1977

TABLE 14. Post Amplifiers
Output vs. Input

	Input (Volts)	Output (Volts) 300 I	300 O	500 I	500 O	BiPolar
Lo Gain Out	-10.0	4.72	4.75	4.74	4.72	4.77
	- 8.0	4.53	4.52	4.49	4.54	4.51
	- 6.0	4.03	4.02	3.99	4.03	4.02
	- 4.0	3.53	3.52	3.49	3.53	3.52
	- 2.0	3.03	3.02	3.00	3.03	3.02
	0.0	2.53	2.52	2.50	2.52	2.52
	+ 2.0	2.03	2.02	2.00	2.02	2.03
	+ 4.0	1.53	1.52	1.50	1.52	1.53
	+ 6.0	1.03	1.02	1.01	1.02	1.04
	+ 8.0	0.54	0.52	0.51	0.51	0.54
	+10.0	0.11	0.07	0.05	0.06	0.09
Med Gain Out	-2.0	4.71	4.72	4.75	4.74	4.77
	-1.6	4.50	4.53	4.52	4.47	4.53
	-1.2	4.00	4.03	4.02	3.97	4.02
	-0.8	3.51	3.53	3.52	3.47	3.52
	-0.4	3.01	3.03	3.01	2.97	3.02
	0.0	2.51	2.53	2.51	2.47	2.51
	+0.4	2.01	2.03	2.00	1.98	2.01
	+0.8	1.51	1.53	1.50	1.48	1.51
	+1.2	1.01	1.03	1.00	0.98	1.00
	+1.6	0.52	0.53	0.49	0.48	0.50
	+2.0	0.07	0.07	0.06	0.06	0.08
High Gain Out	-0.40	4.72	4.76	4.70	4.73	4.69
	-0.32	4.51	4.53	4.50	4.54	4.55
	-0.24	4.00	4.03	4.00	4.04	4.05
	-0.16	3.50	3.53	3.49	3.53	3.54
	-0.08	2.99	3.02	2.98	3.03	3.04
	0.00	2.48	2.53	2.50	2.53	2.53
	+0.08	1.99	2.01	1.99	2.01	2.02
	+0.16	1.50	1.52	1.48	1.52	1.52
	+0.24	0.98	1.01	0.98	0.99	1.01
	+0.32	0.48	0.52	0.47	0.50	0.49
	+0.40	0.06	0.07	0.05	0.06	0.06

TABLE 15. Peak Detectors - Output vs. Input

Input (Volts)	Output (Volts)	
	Positive	Negative
+10.0	5.00	0.0
+8.0	4.02	0.0
+6.0	3.05	0.0
+4.0	2.06	0.0
+2.0	1.01	0.0
0.0	0.0	+0.2
-2.0	0.0	0.99
-4.0	0.0	1.97
-6.0	0.0	2.97
-8.0	0.0	3.95
-10.0	0.0	4.95

TABLE 16. Camera Frame Number Encoding and Display

Display Digit (Decimal)		Input Binary Digits and Weight 0	4	2	1
Mode Counter	D1	0	A_2	A_1	A_o
	D2	0	0	0	A_3
Program Counter	D3	0	B_2	B_1	B_o
	D4	0	0	0	B_3
	D5	0	C_2	C_1	C_o
	D6	0	0	0	C_3

A_n Binary Digits From ÷ 12 Mode Counter
B_n Binary Digits From First ÷ 16 Program Counter
C_n Binary Digits From Second ÷ 16 Program Counter
"0"'s Indicate Wired Grounds At Display Electronics Input

Film Display

$D_2 \; D_1 \, . \, D_4 \; D_3 \; D_6 \; D_5$

Arrows Indicate Carries

TABLE 17: PCM Assignments Charging Rocket A31.603

32 Word Frame PCM 625 Frames/Second 11 Bits/Word
Most Significant Bit is Parity 10 Bits Conversion Odd Parity
0-5 Volts (telemetry) 1023 bits = 5 volts
Frame Sync Code - 10110111000
B Subcom " " - 01001000111
C " " " - 11100010010

MAIN FRAME

WORD NO.	FUNCTION
1	PIBS Ion Beam Current
2	" " " Voltage
3	" Discharge Current
4	" " Voltage
5	" Keeper Current
6	" " High Voltage
7	" " Low "
8	" Cathode Heater Current
9	" Accel. Current
10	" Decel. "
11	" Neutralizer Heater Current
12	" " Bias Voltage
13	" " Emission
14	" Net Current
15	MTM Program Mode Staircase(12 Modes)
16	"B" Internal Sub-Com
17	RTM RPA Step Staircase (6 steps/mode)
18	PIBS PPA Inverter Current
19	" " " Voltage
20	"D" External Sub-Com
21	PIBS Neutralizer Polarity Flag
22	RPA No. 1 Log I Output
23	" No. 2 " " "
24	"C" Internal Sub-Com
25	Retarding Voltage Low
26	" " High
27	EBS Gun Cap Current
28	" " Frame "
29	"E" External Sub-Com
30	Squib System Monitor 1
31	" " " 2
32	Frame Sync

WORD NO.	FUNCTION
B SYNC	
B1	Accelerometer B+
B2	Support Battery Monitor
B3	Camera " "
B4	Boom Release "
B5	Aerospace/RPA Doors
B6	Caps/Camera Door
B7	Instrument Battery Monitor
B8	TEP 1 High Gain Outer 500
B9	" 1 Medium " " "
B10	" 1 Low " " "
B11	" 2 High " Inner "
B12	" " Medium " " "
B13	" " Low " " "
B14	" 3 High " Outer 300
B15	" " Medium " " "
B16	" " Low " " "
B17	" 4 High " Inner "
B18	" " Medium " " "
B19	" " Low " " "

WORD NO.	FUNCTION
C SYNC	
C1	Y Magnetometer
C2	X "
C3	Accelerometer Eo
C4	Tip/Boom/Doors

WORD NO.	FUNCTION
D SYNC	Power Monitor #1 (Beam Instrumer
D1	Aerospace Sensor #1 Voltage
D2	" " " Current
D3	" " #2 Voltage
D4	" " " Current
D5	" Thermistor #1
D6	" " "
D7	SRI Positive Peak
D8	SRI Negative Peak
D9	SRI # DC Level
D10	SRI Positive Pulse Counts Low Th
D11	" Negative " " " "
D12	" Positive " " High "
D13	" Negative " " " "
D14	Camera Shutter Motion
D15	Bi-Polar Voltmeter Low Gain
D16	" " Medium Gain
D17	" " High "
D18	" " Positive Pea
D19	" " Negative Peal

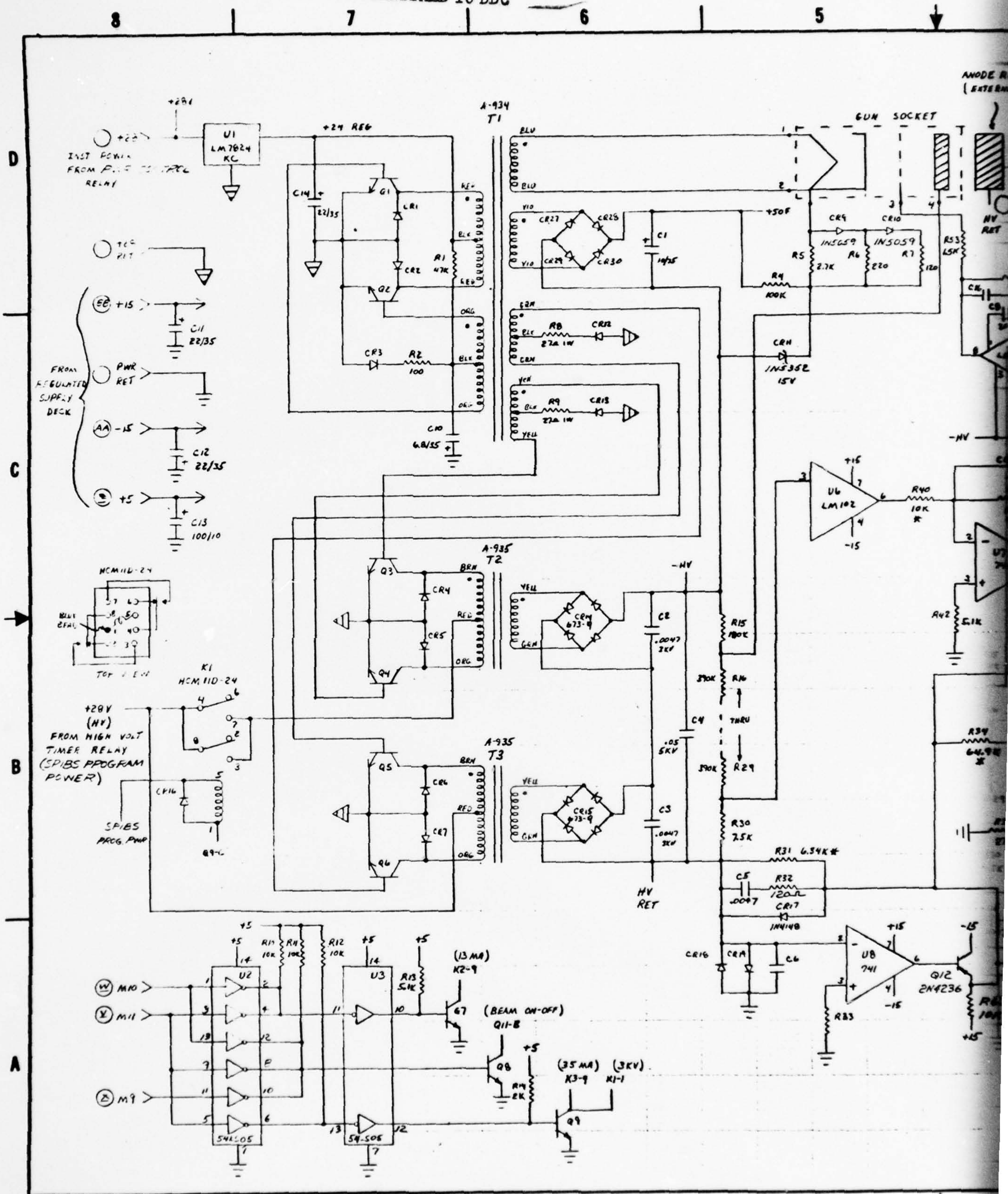
WORD NO.	FUNCTION
E SYNC	Power Monitor #2 (TEP FILS & KV
E1	+550V Monitor
E2	-550V "
E3	+350V "
E4	-350V "
E5	+5V "
E6	-5V "
E7	+15V "
E8	-15V "
E9	Pressure Monitor
E10	Electron Gun High Voltage Mon
E11	" " Compartment Temp
E12	PIBS Xenon Tank Pressure
E13	PPA Temperature PIBS
E14	TEP 1 Inner 300 Filament
E15	" 2 Outer " "
E16	" 3 Inner 500 "
E17	" 4 Outer " "
E18	P1 Program Staircase
E19	P2 " "

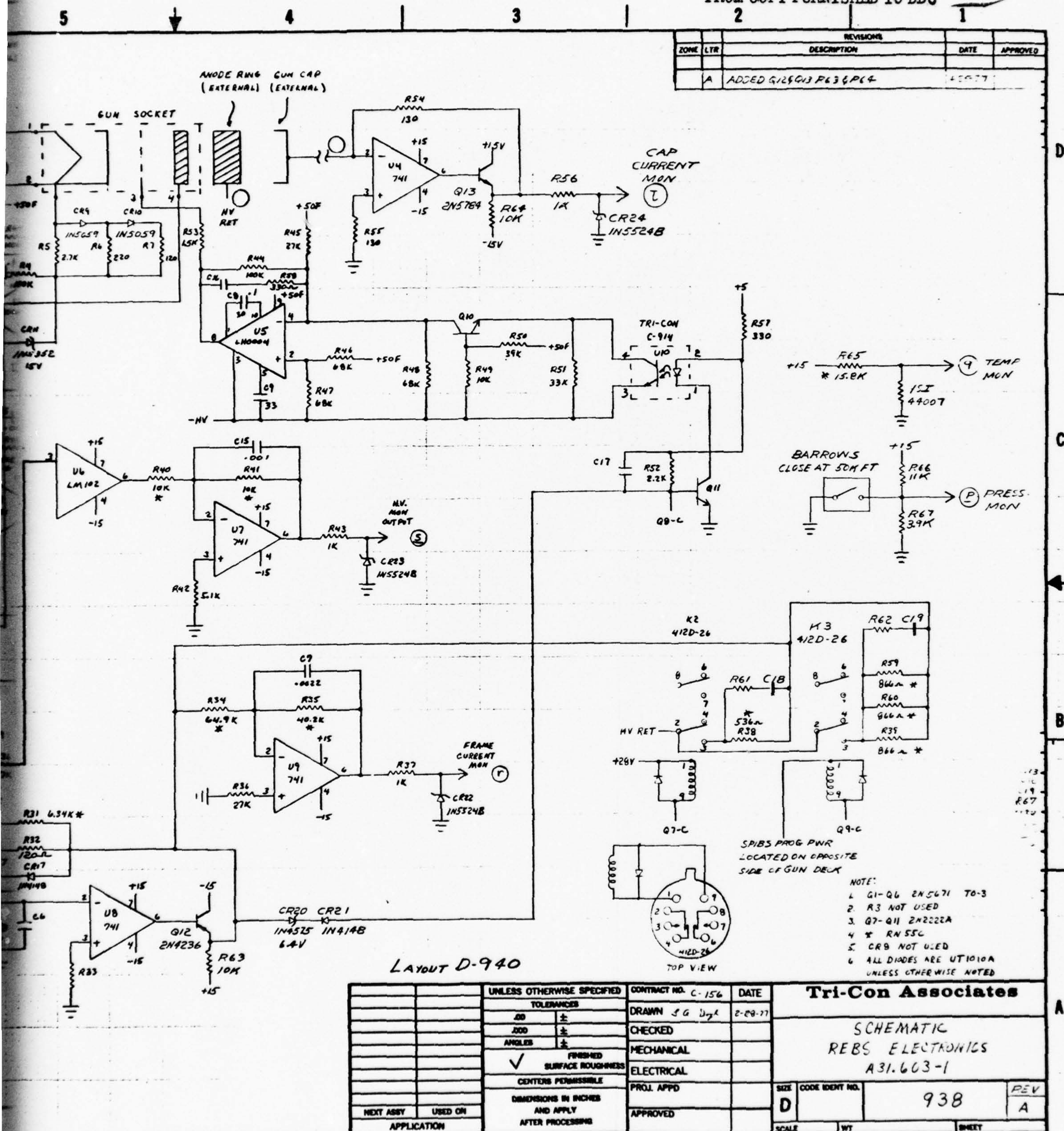
TABLE 18: Event Sequence - A31.603
Flight Data

Function Versus Time After
Launch and Altitude

Time (Sec)	Altitude (Km)	Function
53	53	Motor Burnout
64	74	Despin
66	78	Motor Separation
69	83	Tip, Boom Doors, Surface Potential Monitor Door, RPA #2 - Blown
71	87	RPS #1 Door, Camera Door - Blown
81	105	TEP and RPA H.V. On, TEP Fils. On
87	114	Electron Gun Cap Blown
94	125	Camera On
95*	127	500 Volt TEP Boom Extende-
103	139	Ion Beam Program Power On
157	205	Electron Beam On (First Sign of Beam After Cap Open).
264	257.7	Apogee
443	112	Instrument Power Off

*300 Volt TEP Boom Never Fully Extended


8
7
6
5
D
C
B
A
+28V
INST POWER
U1
LM7824
KC
+24 REG
A-934
T1
GUN SOCKET
ANODE
+50F
CR9
CR10
1N5059
1N5059
R4
100K
R5
2.7K
R53
1.5K
HV RET
+15
PWR RET
-15
+5
FROM REGULATED SUPPLY DECK
C11
22/35
C12
22/35
C13
100/10
C14
22/35
C10
6.8/35
R1
47K
R2
100
CR3
R8
27Ω 1W
R9
27Ω 1W
CR14
1N5352
15V
-HV
U6
LM102
R40
10K
HCM11D-24
TOP VIEW
K1
HCM11D-24
A-935
T2
A-935
T3
+28V
(HV)
FROM HIGH VOLT TIMER RELAY
(SPIBS PROGRAM POWER)
SPIBS
PROG PWR
C2
.0047
3KV
C4
.05
5KV
C3
.0047
3KV
R15
180K
R16
THRU
R29
390K
R30
7.5K
R31 6.34K
R32
120Ω
CR17
1N4148
C5
.0047
HV RET
R34
64.9K
R42
5.1K
U8
741
Q12
2N4236
R33
U2
U3
54LS05
54-S05
M10
M11
M9
R10
10K
R11
10K
R12
10K
R13
5.1K
(13 MA)
K2-9
(BEAM ON-OFF)
Q11-E
Q7
Q8
R14
2K
(35 MA)
K3-9
(3KV)
K1-1
Q9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A | ADDED Q12 & Q13 R63 & R64
ANODE RING (EXTERNAL)
GUN CAP (EXTERNAL)
GUN SOCKET
HV RET
CAP CURRENT MON
R54 130
U4 741
Q13 2N5764
R64 10K
R56 1K
CR24 1N5524B
R55 130
U5 LH0004
Q10
R50 39K
R46 68K
R48 68K
R49 10K
R51 33K
R47 68K
C9 33
TRI-CON C-914
U10
R57 330
R65 * 15.8K
TEMP MON
ISI 44007
BARROWS CLOSE AT 50K FT
R66 11K
R67 3.9K
PRESS. MON
U6 LM102
R40 10K
C15 .001
R41 10K
U7 741
R43 1K
H.V. MON OUTPUT
CR23 1N5524B
R42 5.1K
C17
R52 2.2K
Q11
Q8-C
K2 412D-26
K3 412D-26
R62 C19
R61 C18
R59 866Ω *
R60 866Ω *
R39 866Ω *
R38 536Ω *
HV RET
+28V
Q7-C
Q9-C
C7 .0022
R34 64.9K *
R35 40.2K *
U9 741
R36 27K
R37 1K
FRAME CURRENT MON
CR22 1N5524B
R31 6.34K *
R32 120Ω
CR17 1N4148
U8 741
Q12 2N4236
R63 10K
R33
CR20 1N4525 6.4V
CR21 1N4148
SPIBS PROG PWR LOCATED ON OPPOSITE SIDE OF GUN DECK
TOP VIEW
NOTE:
1. Q1-Q6 2N5671 TO-3
2. R3 NOT USED
3. Q7-Q11 2N2222A
4. * RN55C
5. CR9 NOT USED
6. ALL DIODES ARE UT1010A UNLESS OTHERWISE NOTED
LAYOUT D-940
UNLESS OTHERWISE SPECIFIED
TOLERANCES
FINISHED SURFACE ROUGHNESS
CENTERS PERMISSIBLE
DIMENSIONS IN INCHES AND APPLY AFTER PROCESSING
NEXT ASSY
USED ON
APPLICATION
CONTRACT NO. C-156
DATE
DRAWN
2-28-77
CHECKED
MECHANICAL
ELECTRICAL
PROJ. APPD
APPROVED
Tri-Con Associates
SCHEMATIC
REBS ELECTRONICS
A31.603-1
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REV A
SCALE
WT
SHEET

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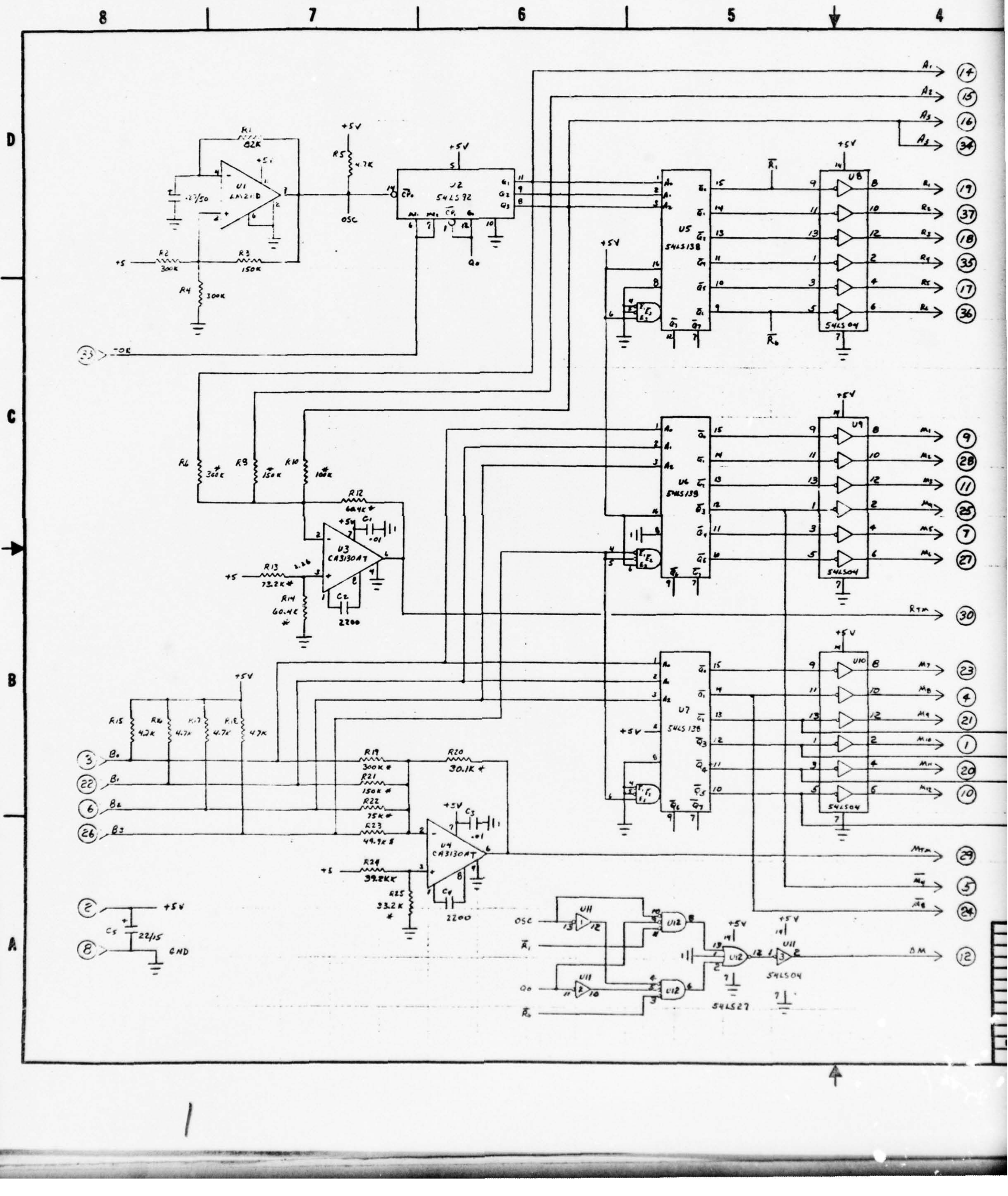

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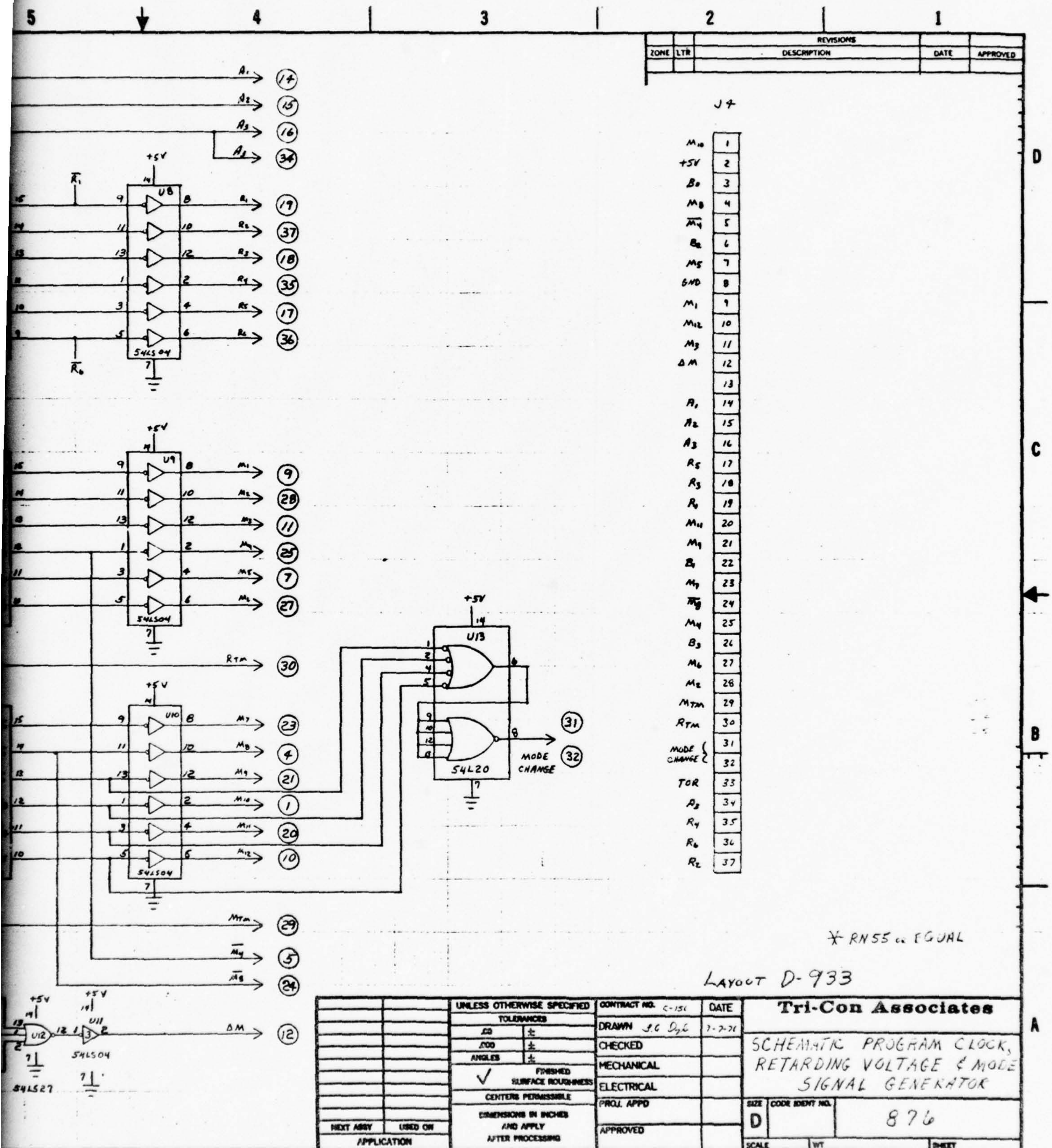

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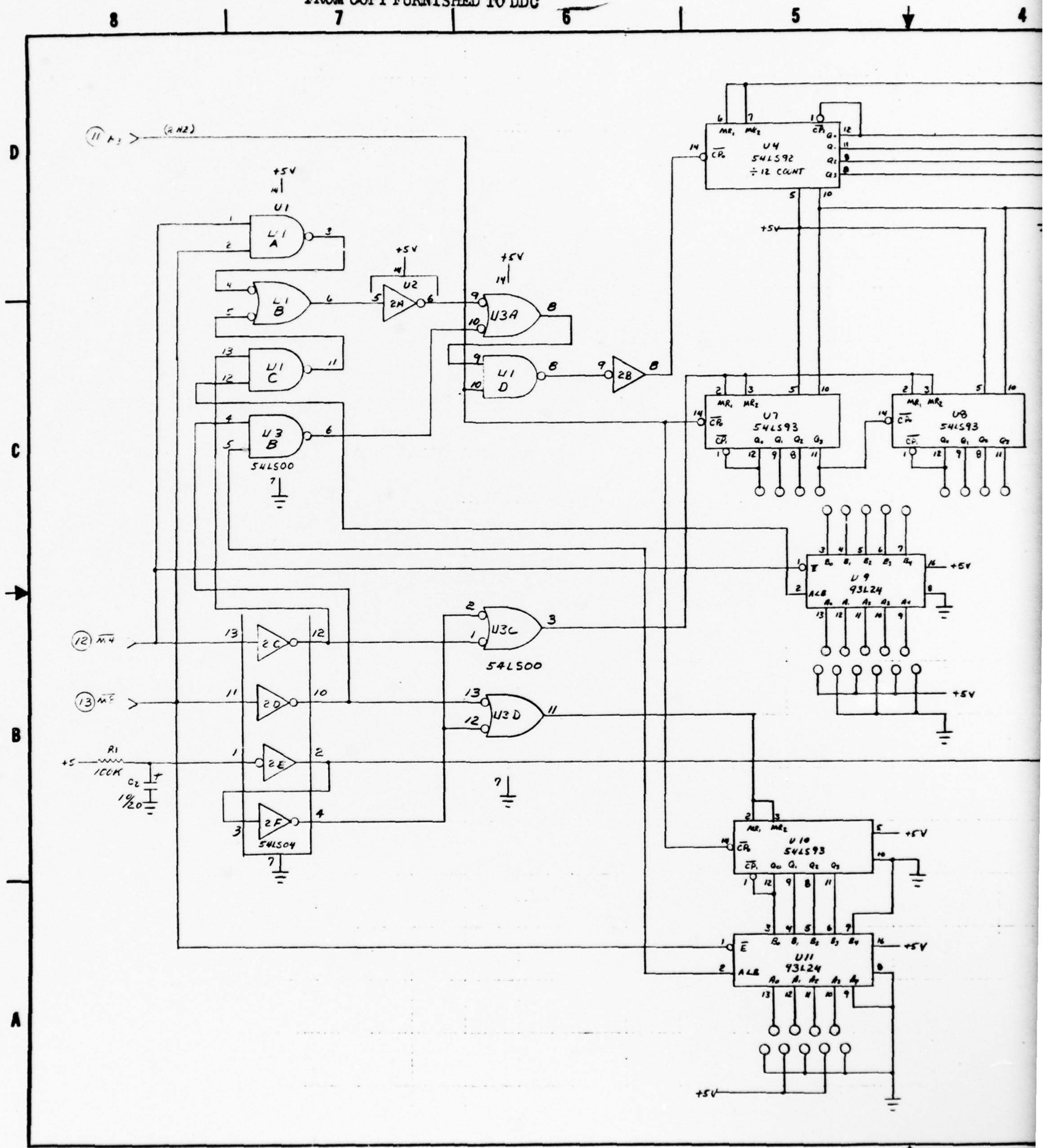

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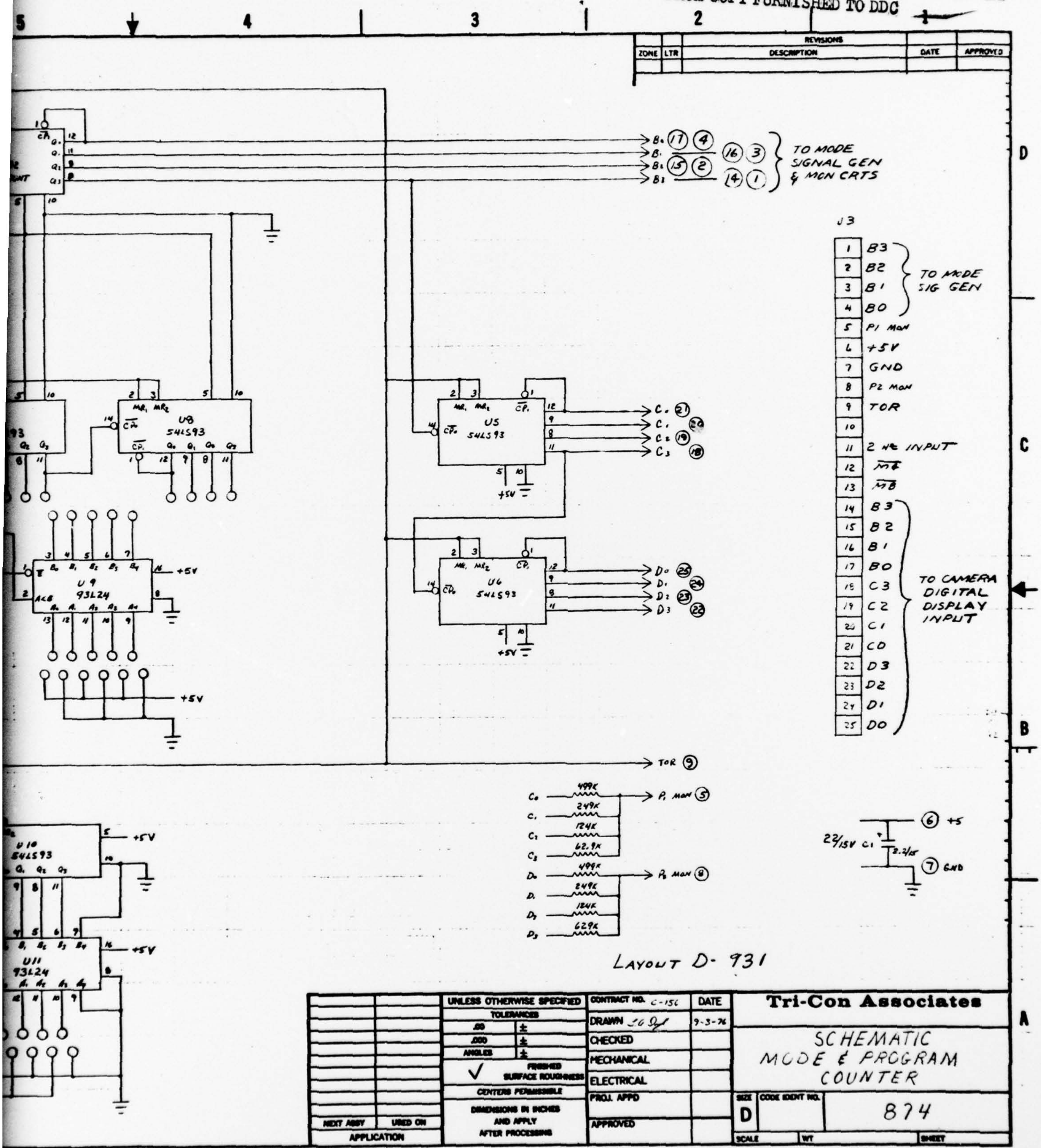
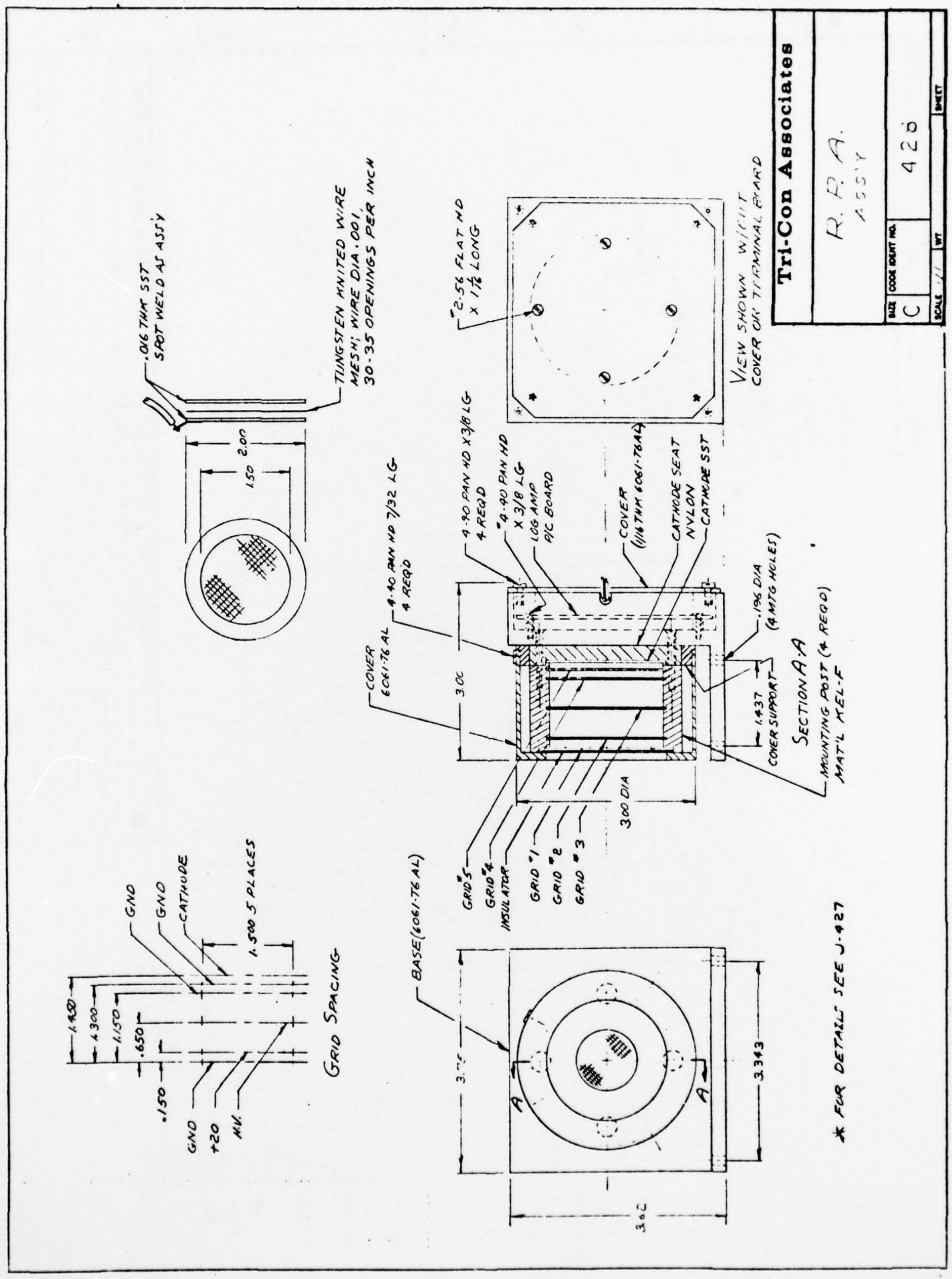
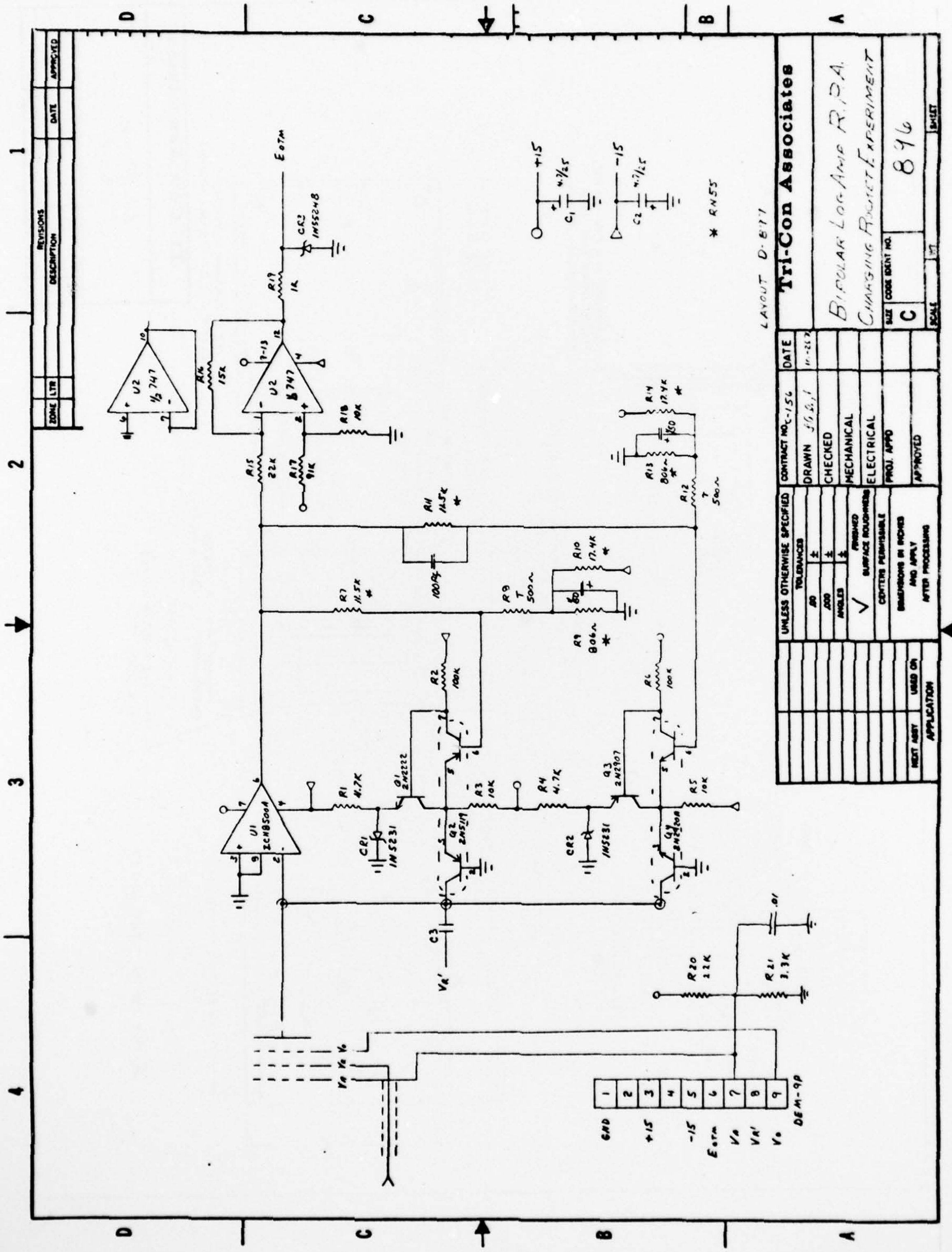



Tri-Con Associates
R. P. A.
ASS'Y
426
SIZE
C
CODE IDENT NO.
SCALE
WT
SHEET
GRID SPACING
.150
.650
1.150
1.300
1.450
GND
+20
H.V.
GND
GND
CATHODE
1.500 5 PLACES
BASE (6061-T6 AL)
GRID #5
GRID #4
INSULATOR
GRID #1
GRID #2
GRID #3
A
A
3.343
3.62
* FOR DETAILS SEE J-427
3.00 DIA
COVER 6061-T6 AL
4-40 PAN HD 7/32 LG 4 REQD
4-40 PAN HD X 3/8 LG 4 REQD
#4-40 PAN HD X 3/8 LG
LOG AMP P/C BOARD
COVER (1/16 THK 6061-T6 AL)
CATHODE SEAT NYLON
CATHODE SST
.196 DIA (4 MTG HOLES)
1.437
COVER SUPPORT
SECTION A-A
MOUNTING POST (4 REQD) MAT'L KEL-F
1.50
2.00
.016 THK SST SPOT WELD AS ASS'Y
TUNGSTEN KNITTED WIRE MESH; WIRE DIA .001, 30-35 OPENINGS PER INCH
#2-56 FLAT HD X 1 1/4 LONG
VIEW SHOWN WITHOUT COVER OR TERMINAL BOARD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Bipolar Log Amp R.P.A.
Charging Rocket Experiment
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DRAWN
CHECKED
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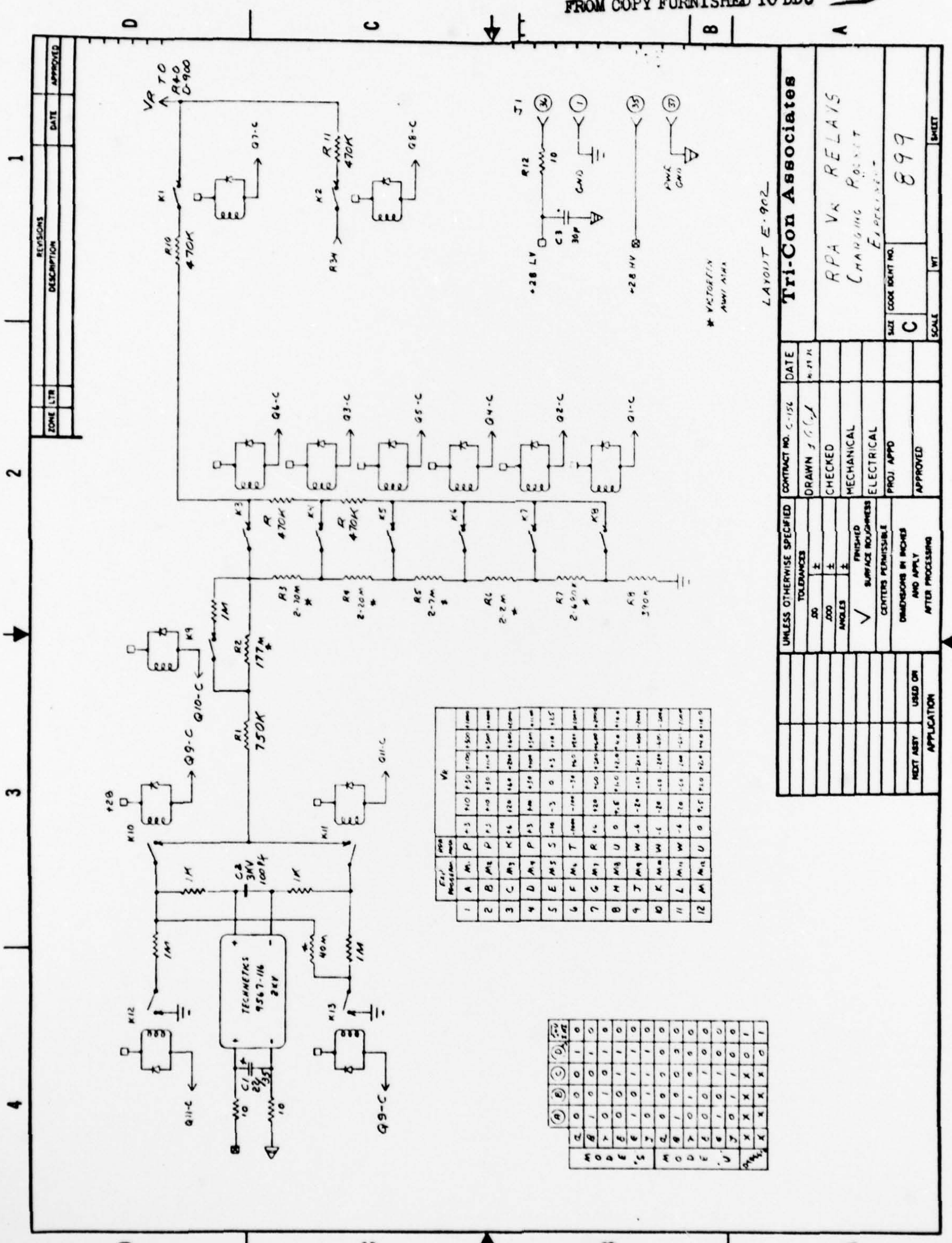
ELECTRICAL
PROJ. APPD
APPROVED
NEXT ASSY
USED ON
APPLICATION
DEM-9P
GND
+15
-15
* RN55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CHECKED
MECHANICAL
ELECTRICAL
PROJ APPD
APPROVED
NEXT ASSY
USED ON
APPLICATION
REVISIONS
ZONE
LTR
DESCRIPTION
DATE
APPROVED
SIZE
C
CODE IDENT NO.
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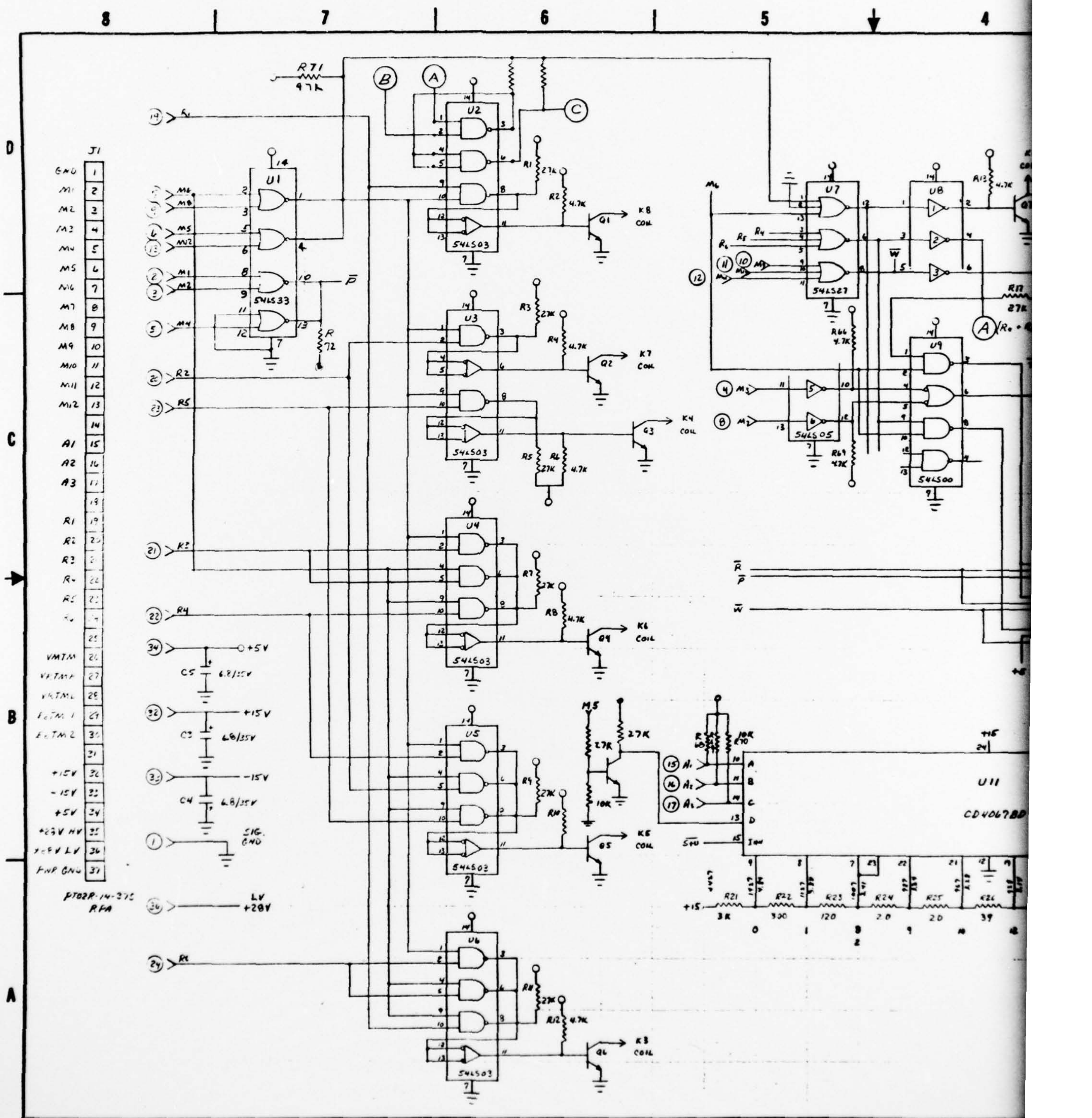
SCALE
WT
SHEET

Lo Gain Out

Med Gain Out

High Gain Out



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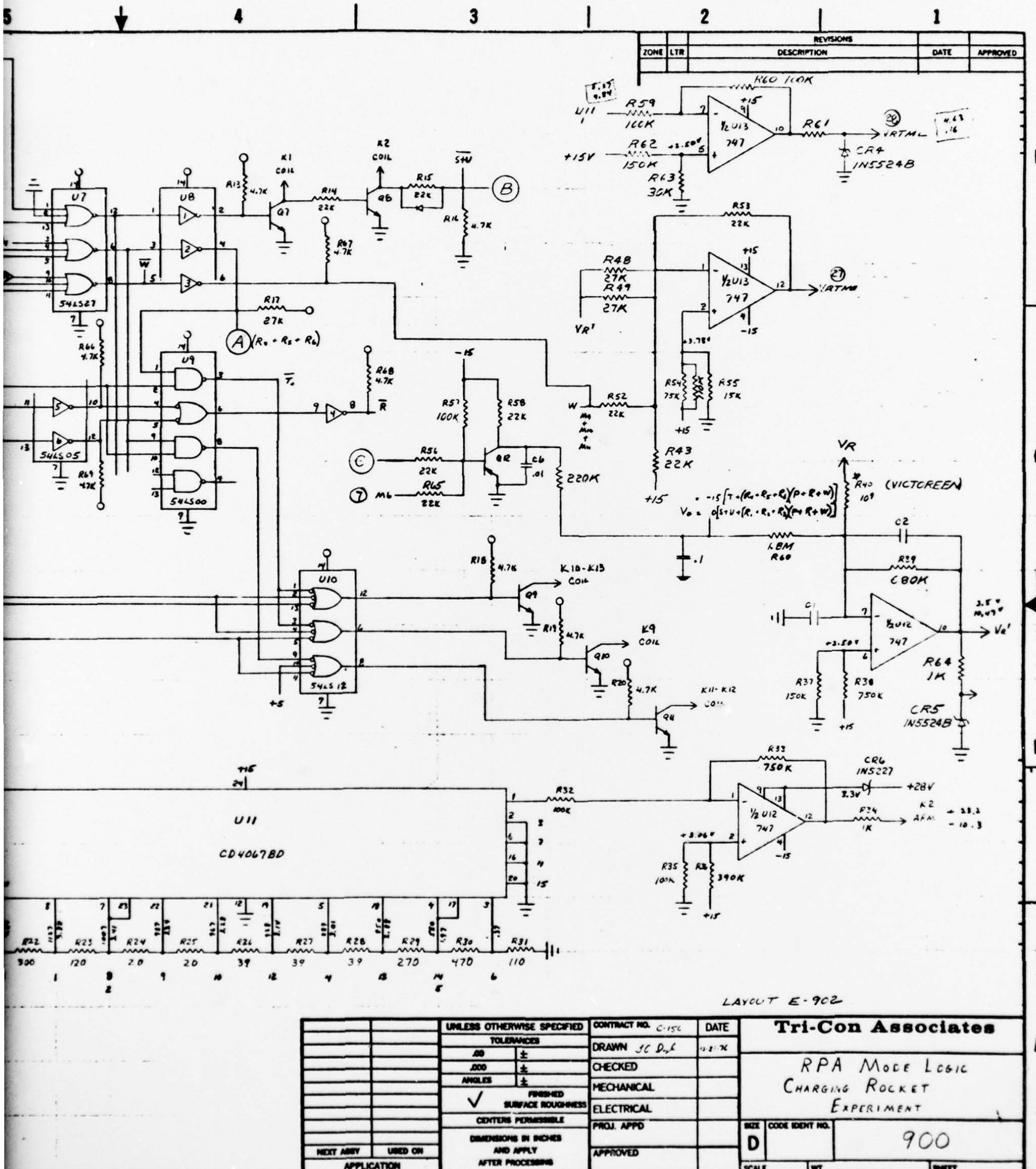
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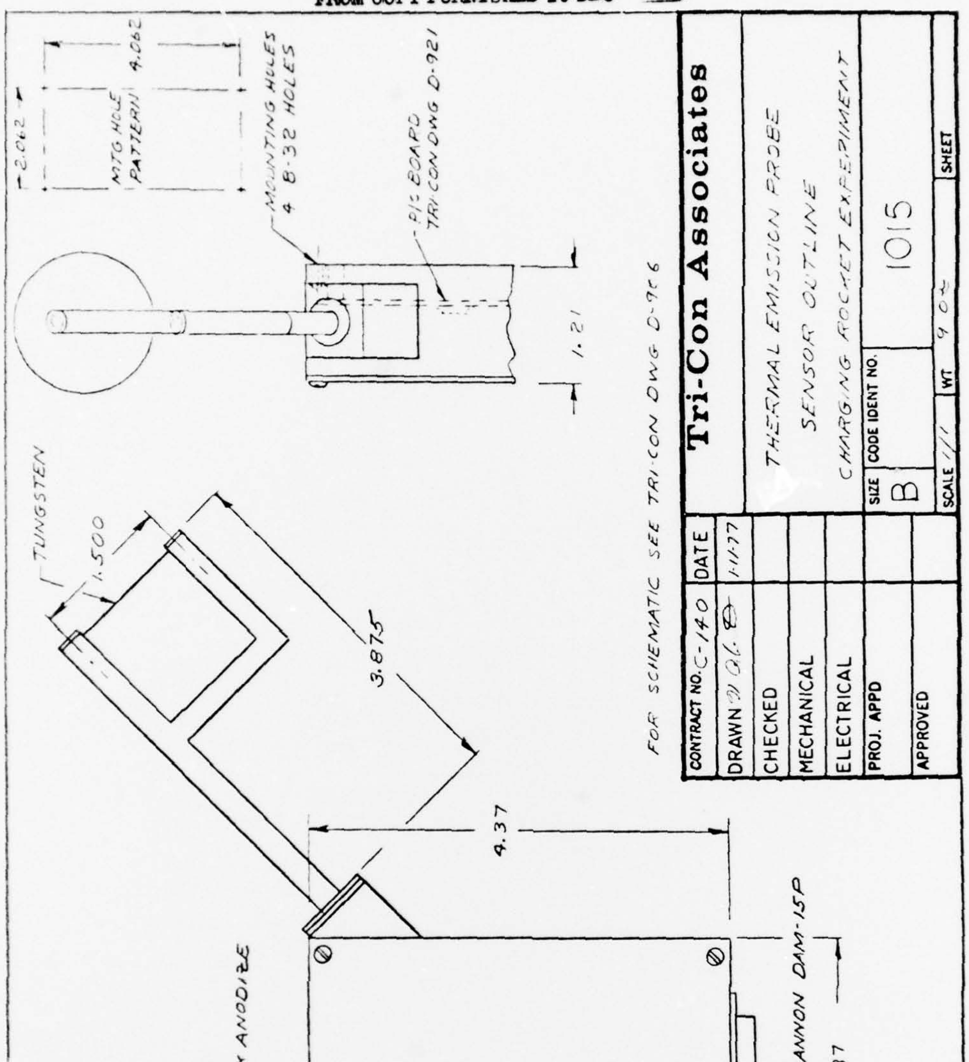
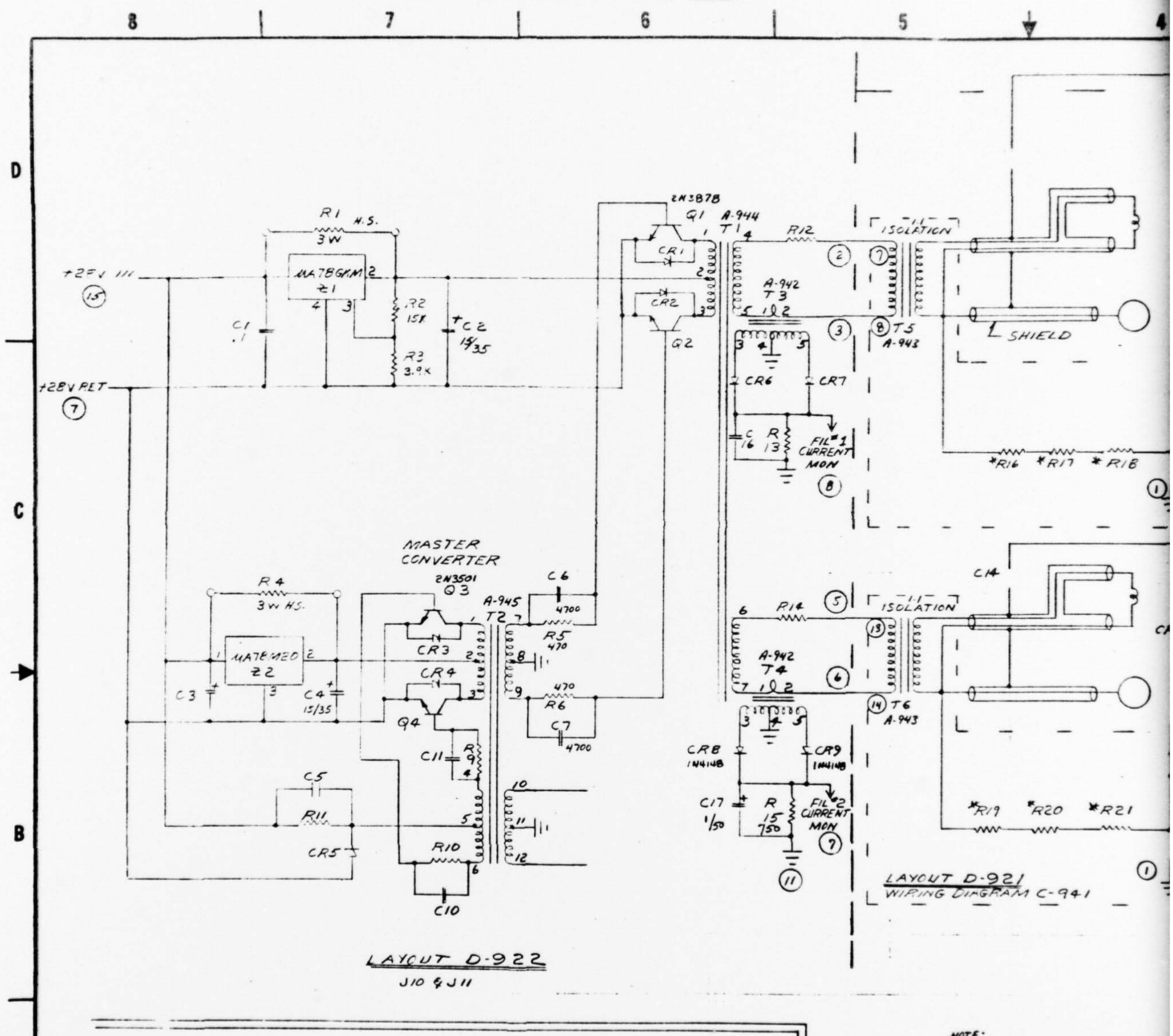
CD4067BD
1/2 U13
747
1/2 U12
747
R60 100K
R59 100K
R62 150K
R63 30K
R61
CR4 1N5524B
R53 22K
R48 27K
R49 27K
R52 22K
R43 22K
R54 75K
R55 15K
VR
R40 (VICTOREEN) 10^9
C2
R39 680K
C1
R37 150K
R38 750K
R64 1K
CR5 1N5524B
R33 750K
CR6 1N5227
+28V
R32 100K
R34 1K
R35 100K
R36 390K
K1 COIL
K2 COIL
K10-K13 COIL
K9 COIL
K11-K12 COIL
Q7
Q8
Q9
Q10
Q11
Q12
R13 4.7K
R14 22K
R15 22K
R16 4.7K
R47 4.7K
R17 27K
R66 4.7K
R68 4.7K
R69 4.7K
R18 4.7K
R19 4.7K
R20 4.7K
R57 100K
R58 22K
R56 22K
R65 22K
220K
C6 .01
1.8M R60
A $(R_4 + R_5 + R_6)$
B
C
M6
W
VR'
Vo'
$V_o = -1.5[T + (R_4 + R_5 + R_6)(P + R + W)]$
R22 300
R23 120
R24 20
R25 20
R26 39
R27 39
R28 39
R29 270
R30 470
R31 110
LAYOUT E-902
UNLESS OTHERWISE SPECIFIED
TOLERANCES
ANGLES
FINISHED SURFACE ROUGHNESS
CENTERS PERMISSIBLE
DIMENSIONS IN INCHES AND APPLY AFTER PROCESSING
NEXT ASSY
USED ON
APPLICATION
CONTRACT NO.
DATE
DRAWN
CHECKED
MECHANICAL
ELECTRICAL
PROJ. APPD
APPROVED
Tri-Con Associates
RPA Mode Logic
Charging Rocket
Experiment
SIZE D
CODE IDENT NO.
900
SCALE
WT
SHEET

2


Tri-Con Associates
THERMAL EMISSION PROBE
SENSOR OUTLINE
CHARGING ROCKET EXPERIMENT
CONTRACT NO. C-140
DATE
DRAWN
1-11-77
CHECKED
MECHANICAL
ELECTRICAL
PROJ. APPD
APPROVED
SIZE
B
CODE IDENT NO.
1015
SCALE 1/1
WT. 9 oz
SHEET
FOR SCHEMATIC SEE TRI-CON DWG D-956
1.50 DIA SPHERE
GOLD PLATED
BLACK ANODIZE
CANNON DAM-15P
TUNGSTEN
MOUNTING HOLES
4 8-32 HOLES
MTG HOLE
PATTERN
P/C BOARD
TRI-CON DWG D-921
3.500
3.875
1.500
4.37
2.37
1.21
2.062
4.062



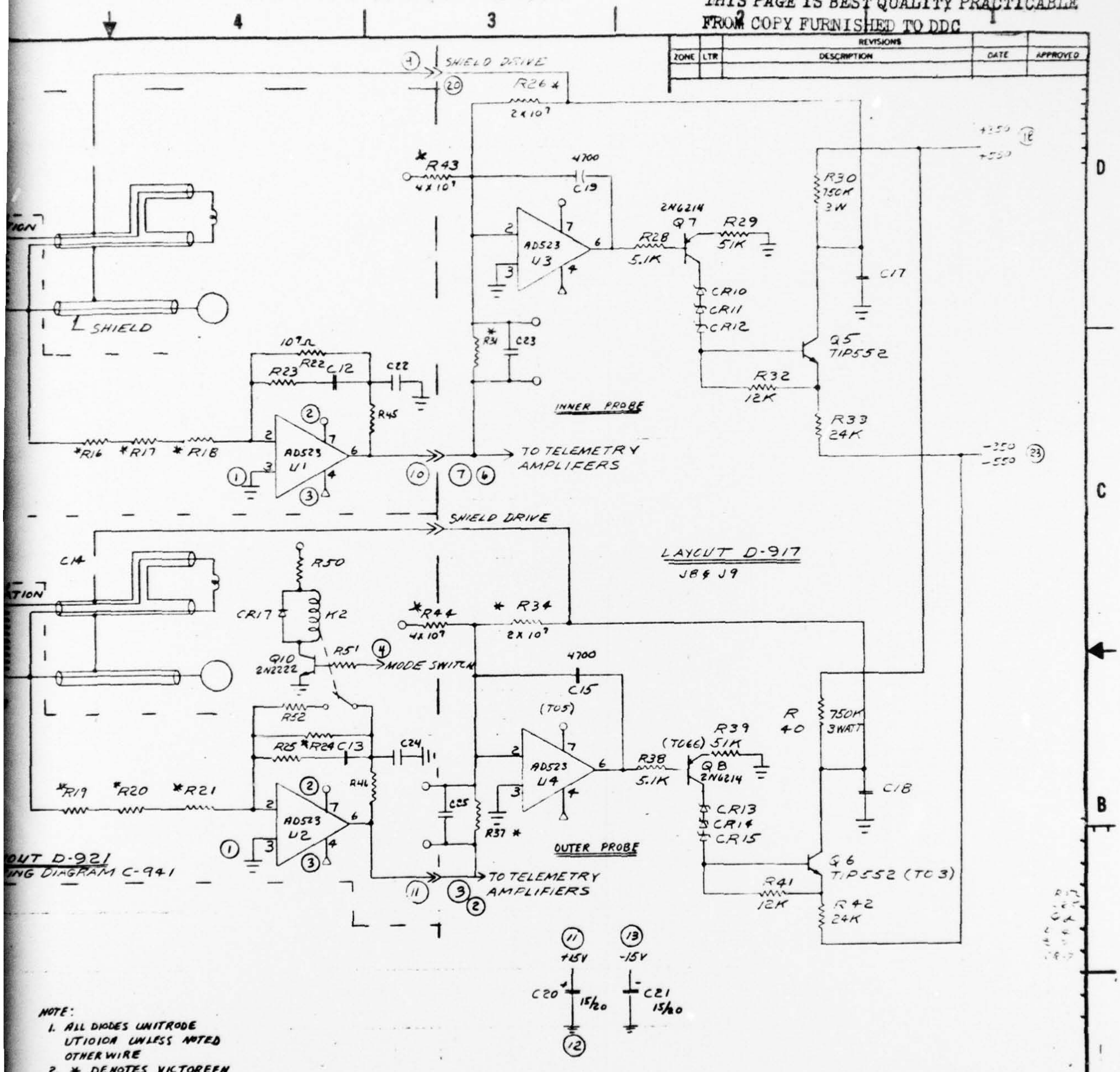
	R16	R17	R18	R19	R20	R21	R22	R24	R31	R37	R52	CR10 - CR15
E[illegible]A 300	10x10^10	10x10^10	10x10^10				10x10^9	10x10^9	.66 meg	.66 meg	4.3x10^8	IN5949
E[illegible]A 500	1[illegible]x10^10	JUMP	JUMP	10x10^10	JUMP	JUMP	2x10^7	2x10^7	400 K	400K		IN5954

COMPONET CHANGES FOR LAYOUT D-917

NOTE #3

NOTE:

1. ALL DIODES UNITRODE UT1010R UNLESS NOTED OTHERWIRE
2. * DENOTES VICTOREEN MOX 1125
3. SEE GRAPH



NOTE:
1. ALL DIODES UNITRODE UT1010A UNLESS NOTED OTHERWISE
2. * DENOTES VICTOREEN MOX 1125
3. SEE GRAPH

UNLESS OTHERWISE SPECIFIED	CONTRACT NO. C-15?	DATE
TOLERANCES	DRAWN	11-1976
.00 ±	CHECKED	
.000 ±	MECHANICAL	
ANGLES ±	ELECTRICAL	
✓ FINISHED SURFACE ROUGHNESS	PROJ. APPD	
CENTERS PERMISSIBLE	APPROVED	
DIMENSIONS IN INCHES AND APPLY AFTER PROCESSING		

NEXT ASSY | USED ON
APPLICATION

Tri-Con Associates

THERMAL EMISSION PROBES
CHARGING POCKET EXPERIMENT

SIZE D | CODE IDENT NO. | 906
SCALE | WT | SHEET

2

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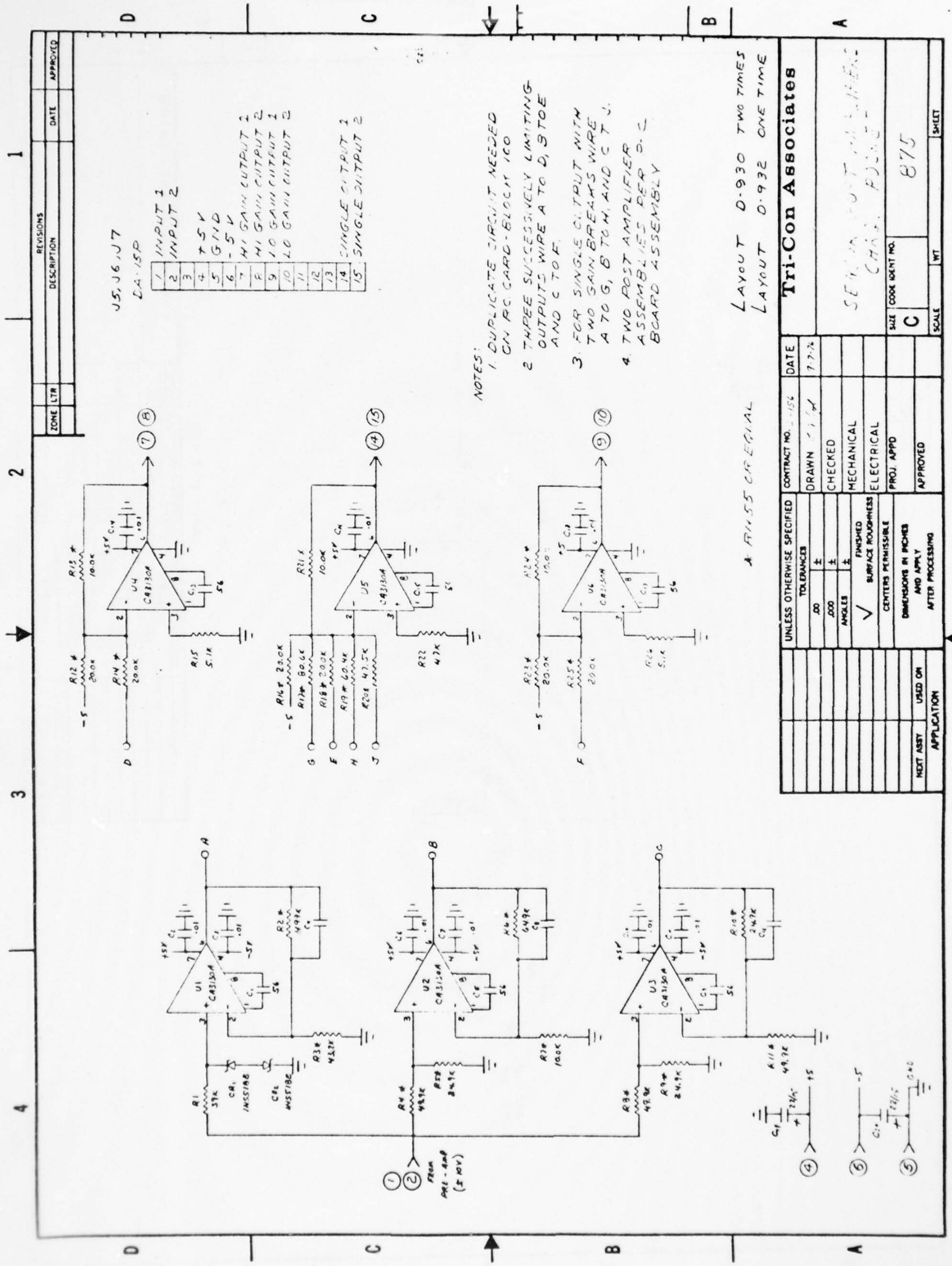

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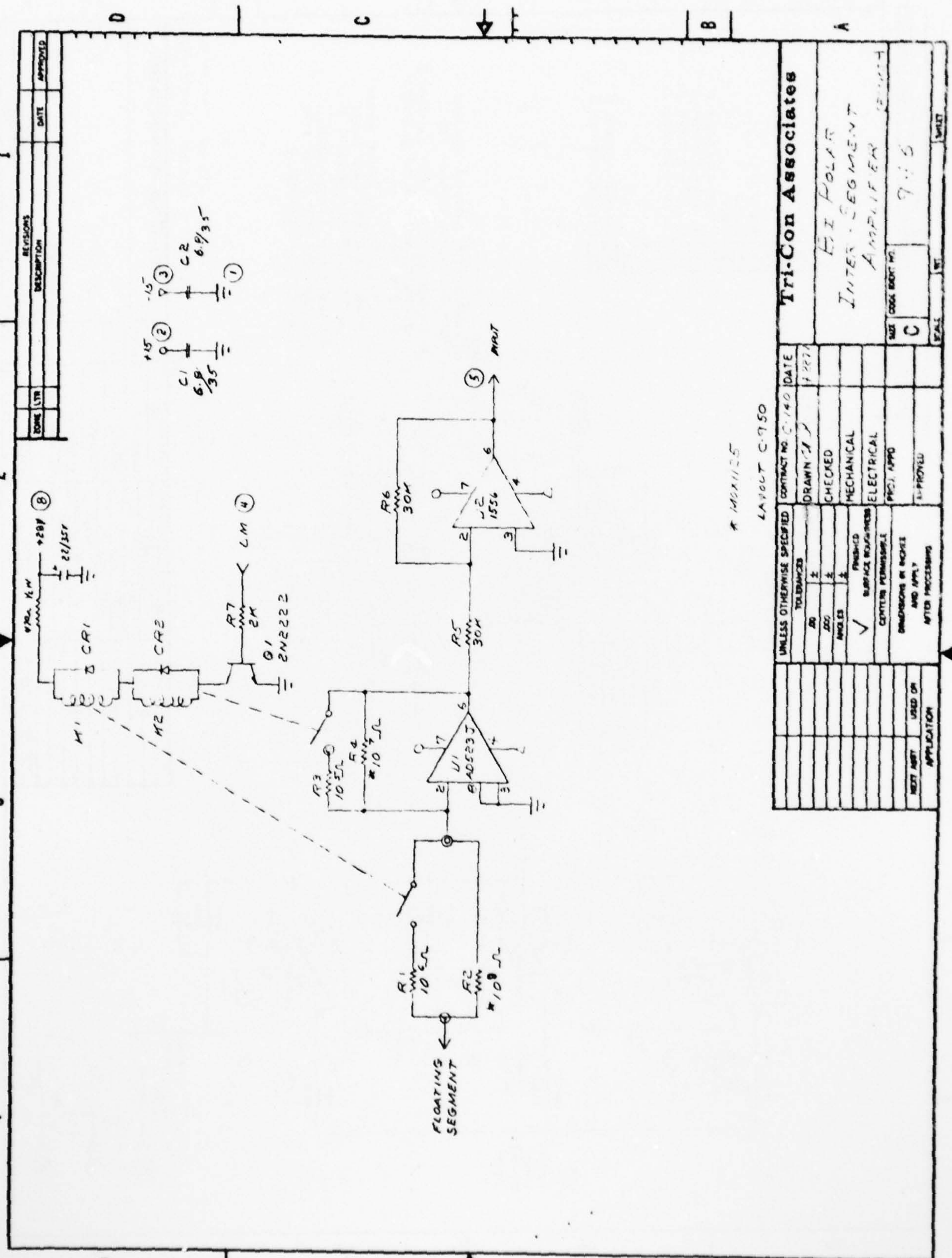

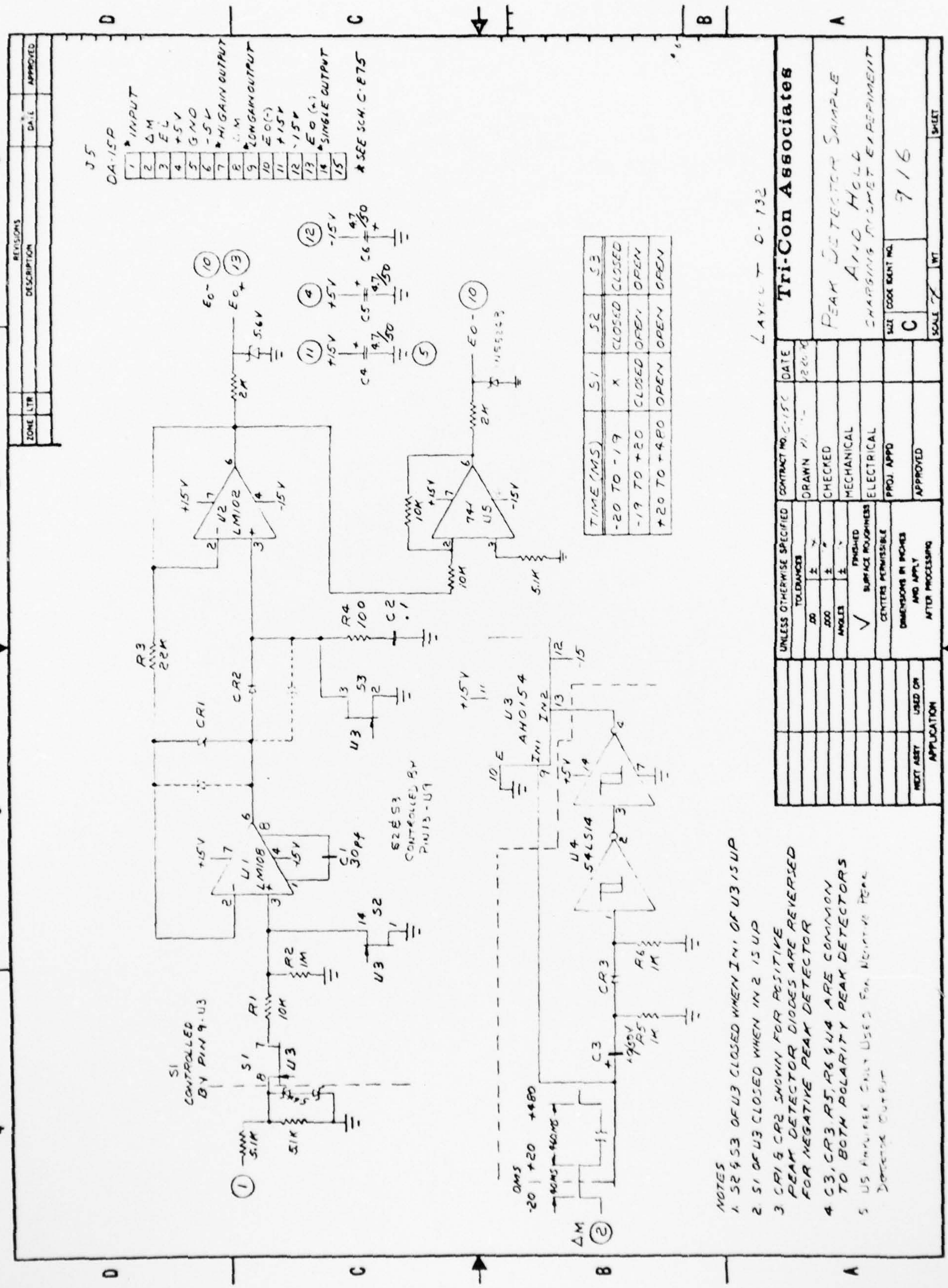
Tri-Con Associates
PEAK DETECTOR SAMPLE
AND HOLD
CHARGING ROCKET EXPERIMENT
716
LAYOUT D-132
TIME (MS) | S1 | S2 | S3
-20 TO -19 | X | CLOSED | CLOSED
-19 TO +20 | CLOSED | OPEN | OPEN
+20 TO +480 | OPEN | OPEN | OPEN
J5
DA-15P
1 INPUT
2 ΔM
3 EL
4 +5V
5 GND
6 -5V
7 HI GAIN OUTPUT
8 ΔM
9 LOW GAIN OUTPUT
10 EO(-)
11 +15V
12 -15V
13 EO(+)
14 SINGLE OUTPUT
15
* SEE SCH. C-875
NOTES
1. S2 & S3 OF U3 CLOSED WHEN IN1 OF U3 IS UP
2. S1 OF U3 CLOSED WHEN IN2 IS UP
3. CR1 & CR2 SHOWN FOR POSITIVE PEAK DETECTOR DIODES ARE REVERSED FOR NEGATIVE PEAK DETECTOR
4. C3, CR3, R5, R6 & U4 ARE COMMON TO BOTH POLARITY PEAK DETECTORS
S1 CONTROLLED BY PIN 9 - U3
S2 & S3 CONTROLLED BY PIN 13 - U3
U1 LM108
U2 LM102
U3 AH0154
U4 54LS14
U5 741
R1 10K
R2 1M
R3 22K
R4 100
C1 30pf
UNLESS OTHERWISE SPECIFIED
DRAWN
CHECKED
MECHANICAL
ELECTRICAL
APPROVED
APPLICATION

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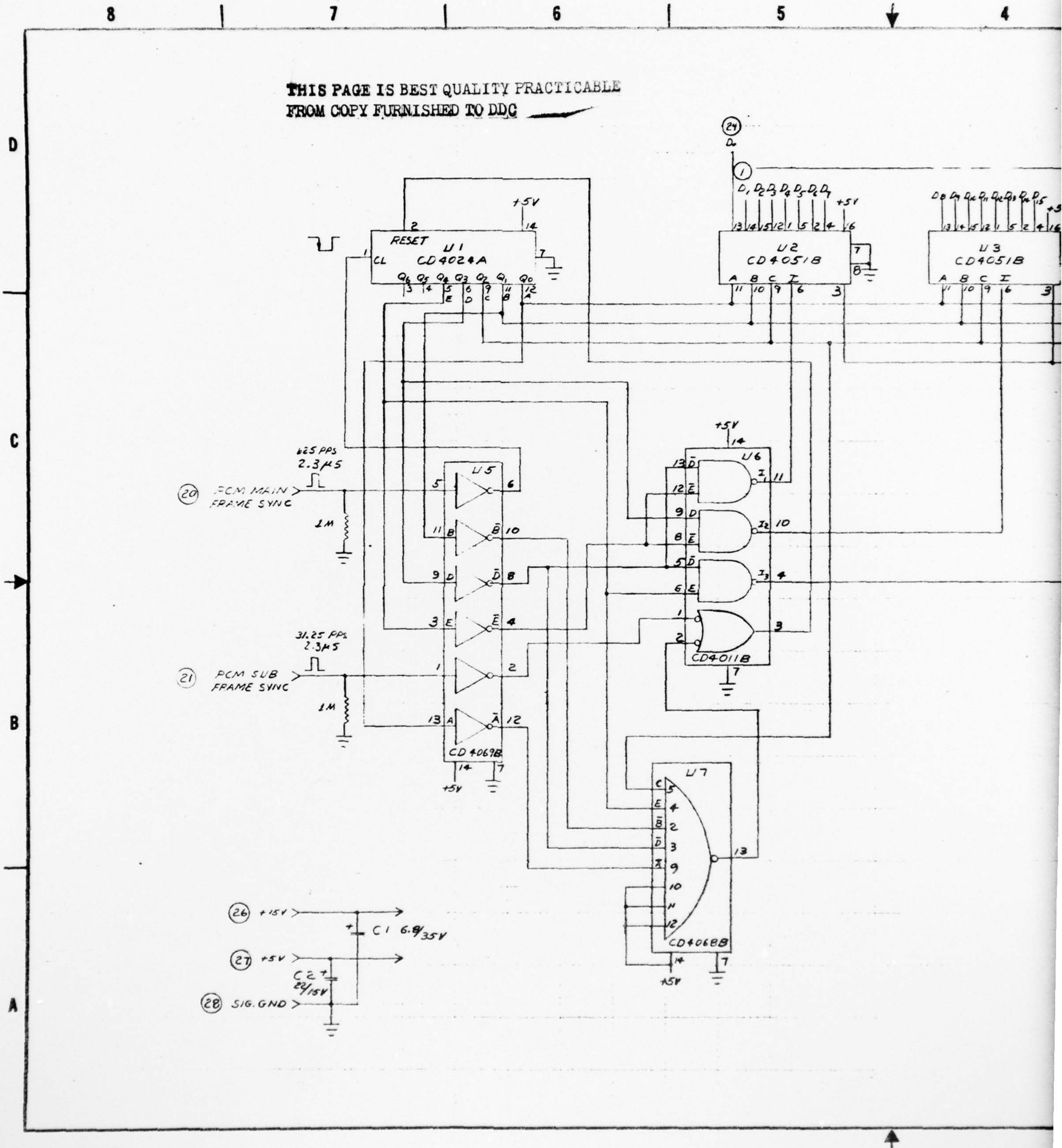
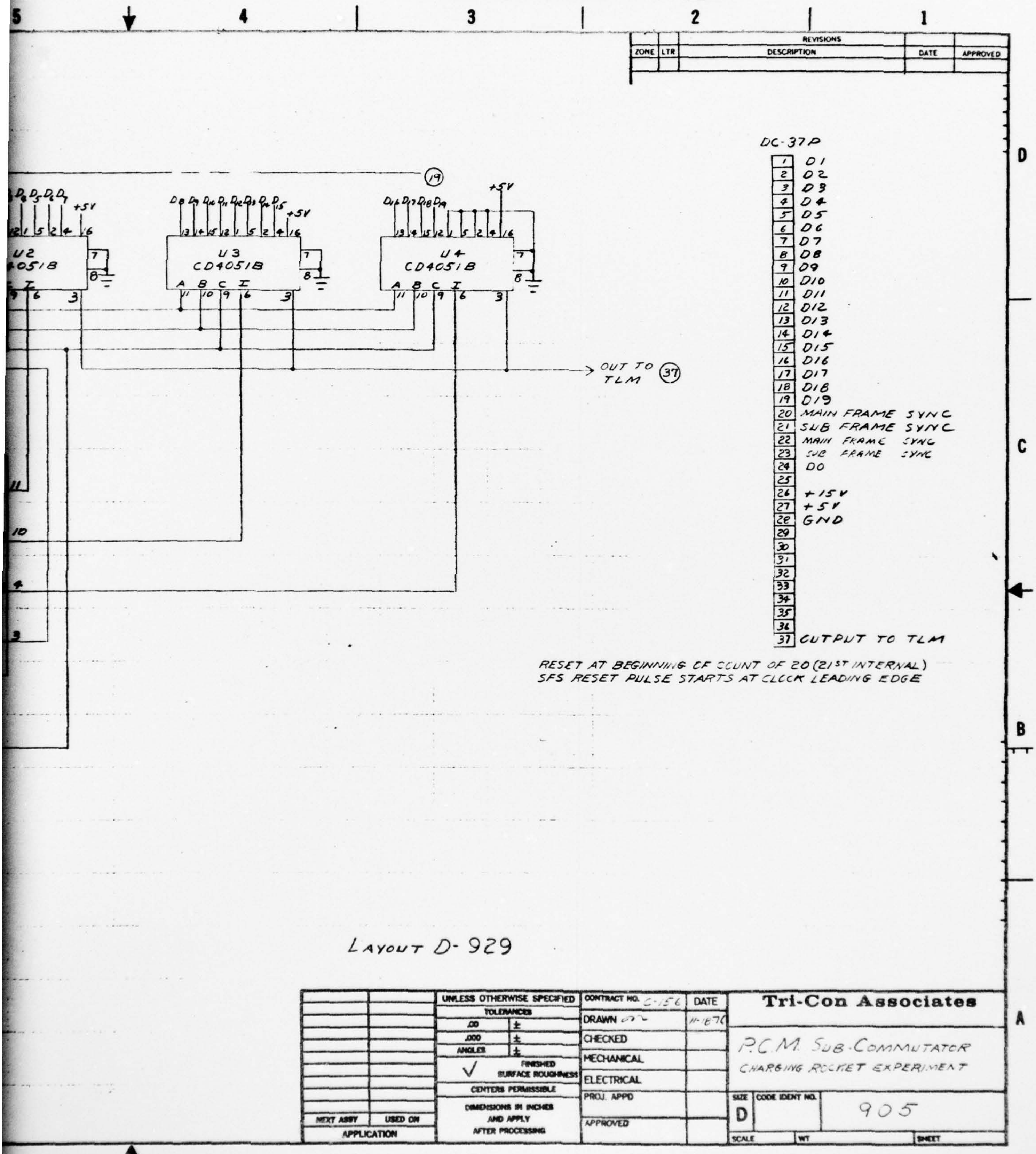


1


REVISIONS
ZONE
LTR
DESCRIPTION
DATE
APPROVED
U2
4051B
U3
CD4051B
U4
CD4051B
+5V
OUT TO TLM
37
19
DC-37P
1 D1
2 D2
3 D3
4 D4
5 D5
6 D6
7 D7
8 D8
9 D9
10 D10
11 D11
12 D12
13 D13
14 D14
15 D15
16 D16
17 D17
18 D18
19 D19
20 MAIN FRAME SYNC
21 SUB FRAME SYNC
22 MAIN FRAME SYNC
23 SUB FRAME SYNC
24 D0
26 +15V
27 +5V
28 GND
37 OUTPUT TO TLM
RESET AT BEGINNING OF COUNT OF 20 (21ST INTERNAL)
SFS RESET PULSE STARTS AT CLOCK LEADING EDGE
LAYOUT D-929
UNLESS OTHERWISE SPECIFIED
TOLERANCES
FINISHED SURFACE ROUGHNESS
CENTERS PERMISSIBLE
DIMENSIONS IN INCHES AND APPLY AFTER PROCESSING
NEXT ASSY
USED ON
APPLICATION
CONTRACT NO.
DATE
DRAWN
CHECKED
MECHANICAL
ELECTRICAL
PROJ. APPD
APPROVED
Tri-Con Associates
P.C.M. SUB-COMMUTATOR
CHARGING ROCKET EXPERIMENT
SIZE
D
CODE IDENT NO.
905
SCALE
WT
SHEET